

## **Historic, Archive Document**

Do not assume content reflects current scientific knowledge, policies, or practices.





Reserve  
aSB951  
.5  
.B49



AD-33 Bookplate  
(1-52)

**NATIONAL**

**A  
G  
R  
I  
C  
U  
L  
T  
U  
R  
A  
L**



**LIBRARY**



**THE BIOLOGIC AND ECONOMIC ASSESSMENT OF  
OXYDEMETON-METHYL**

A report of the oxydemeton-methyl assessment team  
for the Special Review of oxydemeton-methyl

Submitted to the Environmental Protection Agency  
on August 23, 1990

Prepared by the United States Department of Agriculture

In Cooperation with

State Agricultural Experiment Stations  
Cooperative Extension Service  
Other State Agencies  
U.S. Environmental Protection Agency



## PREFACE

This report is a joint project of the U.S. Department of Agriculture and the Cooperating State Land-Grant Universities. This report is prepared by a team of scientists from these organizations in order to provide sound, current scientific information on the benefits of, and exposure to, oxydemeton methyl.

The report is a scientific presentation to be used in connection with other data as a portion of the total body of knowledge in a final benefit/risk assessment under the Special Review process of the registration division of the Environmental Protection Agency (EPA) in connection with the Federal Insecticide, Fungicide, and Rodenticide Act.

Sincere appreciation is extended to the Assessment Team Members and to all others who gave so generously of their time in the development of information and in the preparation of this report.

### The Oxydemeton-methyl Assessment Team

#### Chairman

Mr. Lewis (Buck) Waters  
U.S. Department of the Interior  
BLM 230  
Washington, D.C. 20240

#### Vegetables

Dr. C. J. Eckenrode  
N.Y. State Agric. Experiment Station  
Geneva, NY 14456

Dr. Richard A. Ashley  
University of Connecticut  
Storrs, CT 06268

Dr. Richard W. Straub  
NYAES - Hudson Valley Laboratory  
Highland, NY 12528

#### Fruit

Dr. R.W. Weires  
NYAES - Hudson Valley Laboratory  
Highland, NY 12528

Dr. H.Y. Forsythe  
University of Maine  
Orono, ME 04469

Dr. Helmut Riedl  
Mid-Columbia Experiment Station  
Hood River, OR 97031

Dr. Elizabeth H. Beers  
Tree Fruit Research Center  
Wenatchee, WA 98801

#### Ornamentals

Dr. James E. Appleby  
University of Illinois  
Champaign, IL 61820

Dr. Gordon R. Nielsen  
University of Vermont  
Burlington, VT 05405-0082

#### Mints

Dr. Craig R. Baird  
University of Idaho  
Parma, ID 83660



**Field Crops**

Dr. Z.B. Mayo  
University of Nebraska  
Lincoln, NE 68583

Dr. Harold R. Willson  
Ohio State University  
Columbus, OH

**Alfalfa**

Mr. Ben Simko  
Malheur County Extension Office  
Ontario, OR 97914

Dr. William Brindley  
Utah State University  
Logan, UT 84322-5305

**Citrus**

Dr. Joseph L. Knapp  
Citrus Research & Education Center  
Lake Alfred, FL 33854

**Cotton**

Mr. Lewis Waters  
USDI - Bureau of Land Management  
Washington, D.C. 20240

Dr. Paul Bergman  
USDA - Extension Service  
Washington, D.C.

**Economics**

Dr. Craig Osteen  
USDA - Economic Research Service  
Washington, D.C.

Dr. Armand Padula  
USDA - Agricultural Research Service  
Beltsville, MD







## TABLE OF CONTENTS

<b>EXECUTIVE SUMMARY</b>	1
Purpose of Report	1
EPA Special Review Triggers	1
Summary of Findings	1
<b>INTRODUCTION</b>	5
General Characteristics of Oxydemeton-Methyl	5
Physical and Chemical Properties of Oxydemeton-Methyl	7
Product Identification	7
Hazardous Ingredients	7
Physical and Chemical Properties	7
Fire and Explosion Properties	7
Toxicological Characteristics	7
Employee Protection Recommendations	8
Spill or Leak Procedures	8
<b>OXYDEMETON-METHYL USE ON FRUITS AND NUTS</b>	9
<b>Oxydemeton-methyl Use on Citrus</b>	11
Oxydemeton-methyl Usage	12
<b>Oxydemeton-methyl Use on Brambles</b>	15
Oxydemeton-methyl Usage	17
Alternative Pest Management	17
Potential for Pest Resistance	19
Summary and Conclusions	20
<b>Oxydemeton-methyl Use on Pears</b>	21
Pest Management	22
Oxydemeton-methyl Usage	22
Alternative Chemicals	23
Summary	24
<b>Oxydemeton-methyl Use on Plums and Prunes</b>	25
Pest Management	26
Oxydemeton-methyl Usage	26
Alternative Chemicals	27
Summary	28
<b>Oxydemeton-methyl Use on Non-bearing Fruit Crops</b>	29
Introduction	29
Oxydemeton-methyl Usage	31
Alternative Pest Management	31
Pesticide Resistance	31
Pest Management	32
Pesticide Application Methods	33
<b>Oxydemeton-methyl Use on Strawberries</b>	35
Oxydemeton-methyl Usage	35
Alternative Chemicals	35
Summary	35
<b>Oxydemeton-methyl Use on Filberts</b>	37
Pest Management	37
Application of Pesticides	38
Oxydemeton-methyl Usage and Alternative Chemicals	38
Summary	39



<b>Oxydemeton-methyl Use on Walnuts</b> .....	41
Pest Management .....	41
Application of Pesticides .....	42
Oxydemeton-methyl Usage and Alternative Chemicals .....	42
Summary .....	43
<b>OXYDEMETON-METHYL USE ON VEGETABLES</b> .....	45
Limitations of Analysis .....	46
Summary and Conclusions .....	46
<b>Oxydemeton-methyl Use on Cruciferous Crops</b> .....	49
Alternative Chemicals .....	50
<b>Oxydemeton-methyl Use on Cucurbits</b> .....	53
Alternative Chemicals .....	54
<b>OXYDEMETON-METHYL USE ON ALFALFA</b> .....	61
Pest Management .....	63
Impact on Pollinating Insects .....	64
Comparative Performance Evaluation .....	67
Potential for Pesticide Resistance .....	71
Oxydemeton-methyl Usage .....	76
Economic and Social Impacts of Oxydemeton-methyl Use .....	81
Methods of Analysis .....	84
<b>OXYDEMETON-METHYL USE ON FIELD CROPS</b> .....	86
<b>Oxydemeton-methyl Use on Sorghum</b> .....	86
Oxydemeton-methyl Usage and Alternative Chemicals .....	87
<b>Oxydemeton-methyl Use on Sugarbeets</b> .....	91
<b>Oxydemeton-methyl Use on Mint</b> .....	93
Pest Management .....	93
Oxydemeton-methyl Usage .....	94
Annual Use Patterns .....	95
Summary .....	95
Acknowledgements .....	95
<b>Oxydemeton-methyl Use on Cotton</b> .....	101
Oxydemeton-methyl Usage .....	102
Alternative Chemicals .....	103
Summary .....	103
<b>OXYDEMETON-METHYL USE ON ORNAMENTAL TREES AND SHRUBS</b> .....	105
Pesticide Application Methods .....	105
Oxydemeton-methyl Usage .....	105
Alternative Chemicals .....	106
Summary .....	106
<b>REFERENCES</b> .....	111



## EXECUTIVE SUMMARY

### Purpose of Report

The purpose of this report is to develop biological, exposure, and economic information related to the uses of oxydemeton-methyl (ODM). An pesticide use impact assessment was prepared to evaluate the benefits and risks to humans, animals, nontarget organisms, and the physical environment resulting from registered uses of ODM for the control of insect pests in, on, and around food, and ornamental crops grown in commercial agriculture.

In the Federal Register of October 5, 1987, the Environmental Protection Agency issued a notice of initiation of special review. The basis for this special review was that EPA concluded that ODM has the potential to adversely affect reproduction and has determined that exposure to ODM may pose risks of concern to applicators and mixers/loaders who use products containing ODM. Therefore, the EPA has concluded that products containing ODM meet or exceed the criteria for initiation of Special Review set forth in Title 40, 154.7(a)(2) of the Code of Federal Regulations.

### EPA Special Review Triggers

The EPA after review of a two-generation reproduction study with rats fed at 0, 1, 10, and 50 parts per million of ODM in the diet concluded that vacuolation of the epithelial cells in the corpus area of the epididymis were observed in both the 10 and 50ppm levels of diet dosage. Also noted was parental body weights and testis weight, and increased pup mortality. Based upon these findings, a reproductive no-observed-effect level (NOEL) was established at 1ppm.

Other toxicological effects were reviewed with the following findings: The submitted oncogenicity studies were inadequate and preclude an assessment of the oncogenic potential. A positive mutagenic effect of ODM has been demonstrated and sufficient data indicates that ODM produces a dose-dependent mutation frequency. A 90-day feeding study in rats has allowed the cholinesterase and systemic NOELs to be set at 1ppm.

Oxydemeton-methyl is an organophosphorus insecticide and acaricide used for a wide variety of sites. It may enter the body through dermal contact, ingestion, or inhalation.

### Summary of Findings

Oxydemeton-methyl (ODM) was introduced commercially in 1960 and is registered for use on a number of commodity crops as well as for use in ornamentals and nursery trees and shrubs. Although the use of ODM for pest control has declined over the past 28 years, it remains a viable alternative particularly for mites and aphids. Several areas of benefit from application of ODM include:

- \* effective control of specific, important pests as a major component of integrated pest management (IPM) programs.
- \* use as part of a pesticide resistance program.
- \* valuable alternative to crops where primary control pesticide is also under review.
- \* use in IPM programs where pollinator safety is extremely important.
- \* use in IPM programs where the primary pesticides are becoming ineffective due to developing resistance.



The site described as "ornamentals" would appear to account for a small amount of ODM. Ornamentals in a technical sense includes a large number of species and a large variety of places where they are grown; therefore, the amount of ODM applied on a per site basis is considered quite small. Additionally, on the ornamentals registration, only drench treatments are approved which should reduce exposure to the applicator.

Oxydemeton-methyl is used for the management of insects and mites which attack several important fruit crops. The most extensive usage of ODM on fruit is for aphid control in citrus. ODM is the material of choice in several IPM programs because it is pest selective, has systemic activity, and has a short residual life on the plant. It is usually applied at relatively low dosages to control specific pests. Because of its safety to pollinators, ODM can be used close to bloom to control aphids and mites on several fruit crops. ODM is the only alternative to dicofol for mite control on citrus and brambles. ODM is the preferred material for aphid control on strawberries in the states of Washington and Oregon. The loss of ODM could result in increased usage of broad-spectrum insecticides and miticides, in an attempt to fill the specific niches occupied by ODM in fruit pest management programs.

Oxydemeton-methyl is used for the management of sucking insects and mites that attack a variety of important vegetable crops. The most extensive usage is on crucifers and cucurbits. In many instances ODM is the material of choice for pest management because of its selective properties, system activity, and short residual. It is applied selectively on an average of 1.5 times per crop at relatively low dosages to control specific pests. ODM is employed on 90% of the crucifer acreage (192,143 acres) and on 19% of the cucurbit acreage (56,780 acres). Because of its safety on pollinator insects, ODM is widely used on cucurbits to control aphids and mites at bloom. It is the only alternative to dicofol for mite control on vegetable crops. If ODM was unavailable, very little acreage would be left untreated; however, ODM fills specific niches in vegetable pest management programs and its loss would result in increased useage of broad-spectrum insecticides - thereby increasing total hazards to workers, handlers and the environment.

In most northwest production areas alfalfa seed growers tend to apply insecticides themselves with field sprayers pulled by closed cab tractors. The Columbia Basin district in Washington is the exception with all ODM insecticides applied by aircraft. This preference for private ground application of treatments stems from strong evidence of better performance of the materials when sprayed 2-3' over the canopy with higher volume of spray. Better treatment timing is another advantage particularly when commercial applicators have a backlog of orders. The private applicator often can treat within 12 hours after making a decision based on the latest pest and beneficial counts. 1988 estimates rank ODM as the most preferred treatment in alfalfa for lygus control with 42,861 lbs ai used in the northwest. Naled was second in amount used at 29,331 lbs ai. ODM represents nearly 50% of all treatments targeted for lygus control during the flowering-pollination period.

Price appears to be the major factor limiting the use of ODM on sorghum. Entomologists in both Texas and Oklahoma indicated that ODM could be an important sorghum insect and mite control agent if pesticide resistance occurs, alternative insecticides are banned, or if ODM becomes cost competitive in the future. Based on the small percentage of acres treated with ODM and the number of equally effective and cheaper alternative pesticides, cancellation of ODM for use on sorghum would have minimal immediate effects on sorghum production in the United States.

At present, ODM does not play an important role in the production of sugarbeets in the United States. Price appears to be the major factor limiting its use on sugarbeets. Based on the small number of treated acres and the availability of cheaper, effective alternative insecticides, cancellation of ODM for use on sugarbeets would have minimal immediate effects on sugarbeet production in the United States.

Oxydemeton-methyl is an important and needed insecticide product for most mint producers in the United States. Where it is used, ODM results in higher mint and higher quality oil. The average grower in the Pacific Northwest utilizing ODM is exposed (using closed cab and protective equipment) to only 4 to 8 hours of ODM use per year in a trade-off for gaining several hundred dollars per acre increased quality and production. In addition, ODM is safer on pollinators from adjacent fields and beneficial insects aiding in natural pest control than some of the alternative insecticides.

Although in 1987, less than 3% of the acreage of cotton was treated with ODM, the loss could be substantial if resistance to other insecticides and miticides should develop at some future date. The loss of ODM as an alternative where resistance has developed in aphids, mites, and leafhoppers would remove one of the few cost-effective alternatives available to the cotton states, and would remove a valuable tool in the development of IPM programs. Of the highly productive cotton states, only California finds that aphids are not a major problem.





## INTRODUCTION

### General Characteristics of Oxydemeton-Methyl

Oxydemeton-methyl (ODM) is a systemic insecticide and acaricide use on a wide variety of agricultural products. ODM is commonly sold under the trade name Metasystox-R. It is properly known as S-[2-(Ethyl-sulfinyl) ethyl] O, O-dimethyl phosphorothioate. While the No Observable Effect Level (NOEL) has been established by EPA at 1 mg/kg, it is apparent (Tashenberg, 1975) that in a closed cab system, large margins of safety exist. Thus in calculating risk we believe that for a sixty kilogram person,  $(1 \text{ mg/kg} \times 60 \text{ kg} = 60 \text{ mg/kg})$  60 mg/day would be the permissible NOEL exposure level. To achieve a 100 fold safety factor for these applications, 0.6 mg would be the maximum daily exposure. With this level in mind, one should consider 0.11 ng per 2500 liters of air/hour (Tashenberg, 1975)  $\times 8 \text{ hr day} = .88 \text{ ng}$  of exposure per day or greater than a 680 fold margin of safety (MOS) if all chemical entering the cab is absorbed. Taking 50 percent dermal absorption rate increases further the MOS to greater than 1000 fold.

This is for the closed cab system in California and in most other parts of the nation (California however is the only State in which a closed loading system and closed cab are required). Of the total 148,000 lbs applied in California, greater than 50 percent was applied to 3 cole crops with Broccoli being the most ODM treatment at 45,000 lbs. Al. in 4,964 applications, which averages 9.06 lbs/Application. However, under acres treated, about 95 percent was applied by air. Hours of actual spraying was about 4 hours/day at about 100 acres/hr. and at this rate assuming 400 acres/day, and a total of 90,309 acres treated total gives about 255 spray days of 4 hours. With as few as 25 applicators working we are looking at a maximum of 10 days exposure for the rate discussed for similar closed cab/closed mixing system as previously calculated with the MOS of 7100. Since all other uses in California are far below this rate of use we cannot conceive of problems arising where the closed cab/closed mixing system occur.

Concerning those applicators and mixers wearing only protective clothing. We have used Lavy and Nash studies representing "base case dose rates" computed on 1.0 pound active ingredient per acre (lb. a.i./acre) (1.12 kg a.i./ha) to determine dose. These studies show that the highest dose was 0.13 mg/kg/day for mixer-loaders using little protective equipment for ground vehicle sprayers. Since ODM usual rate is 1/2 lb./acre in many instances, the total exposure is estimated to be 0.065 mg/kg/day which fits well within normal safety parameters based on 0.6 mg/kg/day maximum dose. Therefore with effective safety equipment such as required by the label, we feel that little real problems can be expected from the use of ODM. This report will discuss registered sites for ODM and the relative importance of ODM as an alternative in control of pests on these sites. A number of exposure estimates as shown can be developed from several exposure scenarios of the highest usage sites; ie., those sites most likely to result in dosages exceeding the NOEL.

Oxydemeton-methyl was introduced commercially in 1960 and is registered for use on a number of commodity crops as well as for use in ornamentals and nursery trees and shrubs. ODM is basically registered to control aphids, mites, thrips, leafhoppers, lygus or plant bugs, and flea beetles. Although the use of ODM for pest control has declined over the past 28 years, it remains a viable alternative particularly for mites and aphids. Several areas of benefit from application of ODM include:

- o effective control of specific, important pests as a major component of IPM programs.
- o use as part of a pesticide resistance program.
- o valuable alternative to crops where primary control pesticide is also under review.
- o use in IPM programs where pollinator safety is extremely important.



- o use in IPM programs where the primary pesticides are becoming ineffective due to developing resistance.

## Physical and Chemical Properties of Oxydemeton-Methyl

### Product Identification\*

Product Name: METASYSTOX-R 50% concentrate  
Chemical Family: Organophosphorous pesticide  
Chemical Name: S-[2-(Ethyl-sulfinyl)ethyl] 0,0-dimethyl phosphorothioate  
Synonyms: Metasystemox, oxydemeton-methyl  
T.S.C.A. Status: Registered under FIFRA  
Structure:  $\text{CH}_3\text{O O}$   
 $\text{P-S-CH}_2\text{-CH}_2\text{-S-CH}_2\text{-CH}_3$   
 $\text{CH}_3\text{O}$

### Hazardous Ingredients\*

	CAS #	%	CURRENT TLV
Metasystox-R:	301 - 12 - 2	50	NE
Methyl isobutyl ketone:	108 - 10 - 1	50	50 ppm

### Physical and Chemical Properties\*

Appearance: Clear amber colored liquid  
Odor: Sulfur compounds  
Molecular Wt.: 246.3 (A.I.)  
Melting Point: Less than -10C (A.I.)  
Boiling Point: 106°C @ .0113MBAR  
Vapor Pressure: NE  
Vapor Density (air=1): NE  
Specific Gravity: 1.03  
Stability: Subject to hydrolysis, Unstable in alkaline media  
Volatility: .09 mg./cu. meter @ 20°C  
Solubility: Soluble in water in all proportions  
Soluble in most organic solvents  
Insoluble in petroleum ether

### Fire and Explosion Properties\*

Flash Point °F(C°): 63° F (TCC)  
Flammable Limits -  
Lel: NE  
Uel: NE  
Extinguishing Media: Water spray, DCP, foam

### Toxicological Characteristics<sup>b</sup>

Animal Toxicity -  
Oral, LD50 (ingestion): Male rat 105 mg/kg; female rat 70 mg/kg  
Dermal, LD50 (skin contact): Rabbit approx. 225 mg/kg  
Inhalation, LC50: One-hour exposure (male rats) - greater than 1.320 mg MSR technical/1 (analytical concentration) or greater than 5.0 mg Metasystox-R technical/1 (nominal concentration). Four-hour exposure (male rat) - 0.360 mg/1 (analytical concentration)  
Fish, LC50: Rainbow trout 6.36 ppm (96 hr.); Bluegill 14 ppm (96 hr.)  
Eye Effects: Causes moderate eye irritation  
Skin Effects: The active ingredient (oxydemeton-methyl) is a contact allergin in guinea pigs. Prolonged or frequently reported skin contact causes allergic reactions in some individuals.  
Other: The results of one animal study indicate that METASYSTOX-R may have an adverse effect on rat testes and overall reproductive performance. Based on the results of this animal study, the reproductive no-effect level for METASYSTOX-R is 1 ppm in the diet or 0.05 mg/kg based on body weight, which is the same as the chronic feeding cholinesterase no-effect level in rats.

### Human Effects of Overexposure:

METASYSTOX-R is a toxic chemical, which like other organophosphate compounds inhibits the enzyme cholinesterase. Uncontrolled exposure to METASYSTOX-R can produce symptoms such as nausea, sweating, a sense of tightness in the chest and constricted pupils. Increasing exposure can produce more serious symptoms such as stomach pains, vomiting and diarrhea, excessive exposure can produce symptoms such as stomach pains, vomiting and diarrhea, while grossly excessive exposure can produce symptoms of life threatening effects, such as muscular tremors, uncontrolled mucous secretion, convulsions and coma.



Exposure Guidelines: No specific exposure guidelines have been established for airborne concentrations of METASYSTOX-R. However, workers should avoid breathing vapors and mists containing METASYSTOX-R. Skin contact with the liquid should also be avoided.

#### **Employee Protection Recommendations<sup>b</sup>**

Eye Protection: Splash-proof goggles  
Skin Protection: Latex or Neoprene gloves; rubber boots and apron  
Respiratory Protection: Wear a pesticide respirator jointly approved by the Mining Enforcement & Safety Administration (formerly U.S. Bureau of Mines) and by the National Institute for Occupational Safety & Health under the provisions of 30 CFR Part 11. In Canada, obtain this information from your dealer.  
Ventilation: Maintain exposure levels as low as possible through use of general and local exhaust ventilation.  
Other: Launder clothing daily after use. Wash thoroughly after handling.

#### **Spill or Leak Procedures<sup>b</sup>**

If Material is Released or Spilled: Contain spilled material through use of diking or absorbent materials. Absorb spilled material with absorbent and scrub area with detergent and bleach. Repeat and rinse with water. Avoid skin contact and breathing vapors.  
Waste Disposal Method: Bury absorbed material and contaminated material in EPA-approved landfill or burn in an incinerator approved for pesticide destruction.

NOTE: To apply the NOELs for reproductive effects to the data gathered by this team several scenarios were fitted to the data gathered according to common and regular field procedures. Although this was done by EPA, this team's results from surveys of use mandated another look at the typical dose expected to be received during the application of ODM.

<sup>a</sup>Source: "Technical Information Sheet", Mobay Chemical Corporation, 1984.

<sup>b</sup>Source: "Material Safety Data Sheet", Mobay Chemical Corporation, June 1986.

## OXYDEMETON-METHYL USE ON FRUITS AND NUTS

Oxydemeton-methyl (ODM) [trade name Metasystox-R/] has been used commercially on a wide range of agricultural commodities since 1960. It is currently registered for use on approximately 45 individual commodity crops. Several of the present registered uses are special local need registrations [Section 24(c)] for certain crops and areas not covered by the National label. ODM is presently registered nationally for aphid and mite control on citrus (grapefruits, lemons, and oranges); brambles (raspberries and blackberries); pears; plums and prunes; walnuts; and on non-bearing fruits including: apples, apricots, cherries, crab apples, grapes, nectarines, peaches, plums, prunes, quinces, and citrus. Section 24(c) registrations are for aphid control on filberts and strawberries in Oregon and Washington.

Benefits assessment of ODM usage on fruit crops was conducted by dividing the crops by area and surveying the persons responsible in each state for the information on pesticide usage practices on the particular crops (Willson and Straub, 1988). The results of the surveys were tabulated and the person responsible for each specific section (i.e., crop) made follow-up calls to additional personnel responsible for pest management practices or recommendations in specific areas. This procedure may have ignored the beneficial usage of ODM for certain pests in specific areas or crops, which is unfortunate since the total parameters of ODM benefits may be underestimated. Additionally one must realize that the total volume of material used on a crop or the percentage of the crop treated do not realistically indicate the relative importance of the material to the individual producers themselves.

Aphids are the only insect pests on fruit crops for which ODM is nationally registered as a control (Mobay Corp., 1989). The 24c registrations are more specific, listing the actual species of aphid for which the product is registered. Aphids are widely distributed in all areas of the U.S. and affect all of the registered fruit crops grown in these areas. Aphids reproduce parthenogenetically, thus multiplying rapidly under favorable conditions, while producing overlapping generations. Aphids injure plants by sucking plant juices, thereby reducing plant vigor and subsequent yields. They physically contaminate fresh or processed products by their presence. They cause secondary contamination of the plants or plant products by their production of honey dew, which forms a substrate for the growth of sooty-mold fungi. They also are responsible for vectoring a large number of plant diseases through their feeding activities and dispersive nature. Natural (i.e., biotic) factors (e.g., heavy rainfall, lady beetle larvae, syrphid larvae, several hymenopterous parasites, entomopathogenic diseases, and insectivorous birds) may help to control aphid populations in specific instances. Due to present day commercial grading standards for fresh produce requiring clean, unblemished product, natural controls for aphids generally have to be supplemented by pesticide treatments.

Mites are arthropods distinguishable from insects by having eight rather than six legs. They are found throughout the U.S. and infest all of the fruit crops for which ODM is registered. There are three major groups of mites of agricultural importance on fruits, including the spider mites (Tetranychidae), the eriophyid or rust mites (Eriophyidae), and the phytoseids (Phytoseiidae, i.e., a family of mites predatory on other mite species).

The Tetranychidae or spider mites includes the largest and most damaging of the mite species attacking fruit. Examples of important tetranychid species on fruit includes the two spotted spider mite, Tetranychus urticae Koch, and the European red mite, Panonychus ulmi (Koch). The two spotted spider mite is a very cosmopolitan species infesting over one hundred and fifty different hosts, while the European red mite is restricted to infesting apple or a few other fruits, i.e., pears and plums. The eriophyid mites include species that are quite specific to a particular crop host. Examples in fruit are the citrus rust mite, Phyllocoptruta oleivora (Ashmead), the apple rust mite, Aculus schlechtendali (Nalepa) and the pear rust mite, Epitrimerus pyri (Nalepa). Predatory mites, e.g., the phytoseids, Typhlodromus pyri (Scheuten) and Amblyseius fallacis (Garman), are effective biological control agents which are very



important in integrated mite control programs (Croft, 1975). Unfortunately, the aforementioned predatory species are notoriously susceptible to many pesticides commonly used on fruit crops.

Mites reproduce both sexually and asexually, and can therefore multiply rapidly under favorable conditions, producing a new generation once a week depending upon the species. They have very effective dispersal mechanisms, enabling them to spread over large areas and to colonize widely separated host plants. Mite injury to the plants takes many forms but includes leaf feeding with chlorophyll removal, resulting in "bronzing" of the leaves. Adverse effects noted on various fruit crops as a result of mite leaf feeding included reduced fruit bud initiation, reduced fruit set, increased fruit drop, increased leaf drop, and adverse effects on fruit color, size, or ripeness. In addition, certain mite species feed on the fruits themselves, causing the fruit to have a russeted appearance. Mite egg-laying on the fruit itself has also resulted in such fruit being rejected for shipment to foreign markets. Mites are especially prone to the development of resistance to pesticide materials used for their control. This is because of their high reproductive capacity, short developmental period, and highly dispersive nature. Other insect species not included on the label are controlled by ODM sprays and in fact such species may have assumed greater importance on a particular crop than the original aphid or mite pests. Species not included on the label for fruit crops but listed as being controlled on other crops include leafhoppers, thrips, flea beetles, fleahoppers, and Lygus bugs. Lygus bugs, leafhoppers, and thrips are important pests of fruit which often require control measures. The use of ODM for control of such non-labeled pests will be discussed in the separate fruit crop sections.

Oxydemeton-methyl has the unique properties of being a systemic (ie., it is absorbed into the foliage and travels within the plant sap) as well as both a miticide and insecticide. Usage patterns, as determined from survey respondents, indicated that the material was most often used selectively in specific problem situations at relatively low dosages (0.25 - 0.50 lb AI/acre) and with a minimal number of applications. The chemical's major utility was in situations requiring an insecticide/miticide having one or more of the following attributes: 1) effective against sucking insects; 2) effective against mites; 3) systemic activity; 4) safe on pollinators; and 5) short days-to-harvest interval. Because of the aforementioned rather unique qualities, ODM fills niches that other pesticides currently do not.

## Oxydemeton-methyl Use on Citrus

Joseph L. Knapp  
Citrus Research and Education Center

Research and extension personnel in California, Arizona, Texas, and Louisiana reported that little or no oxydemeton-methyl was used on citrus in their States and continued registration was not critical to their industry. In Florida ODM is recommended and used for the management of aphid pests attacking citrus. ODM is the product of choice in Florida's IPM program based on the length of control obtained, the short worker re-entry period, the relatively low toxicity to honey bees, and the short interval to harvest following treatment (Knapp, et al. 1989).

Prior to a series of freezes in the early and mid 1980's, Florida citrus was a mature industry with approximately 850,000 acres (Table 1). In 1985, the acreage was reduced to 503,000. Florida's total citrus acreage as of January 1988 was 697,929 acres, an increase of 73,437 acres following the freeze years. The current 12 percent increase is a result of extensive new plantings in the southern areas, replanting of frozen out blocks primarily in the northern area, and resetting and inter-planting in existing groves in all growing regions. Total bearing acres of all citrus increased to 521,802 acres up from 510,711 acres in 1986. Non-bearing acreage is up considerably at 176,127 compared to 113,781 acres in 1986 (Fla. Ag. Stat. Ser., 1988).

Table 1. Acreage and value of Florida citrus

	1982	1984	1988
acreage	847,856	761,365	697,929
on tree value <sup>a</sup>	\$713,380	\$849,457	\$889,401

<sup>a</sup>x \$1,000

There are three species of aphids which are economically important citrus pests. These are the spirea aphid, Aphis citricola, Van der Goot, the cotton or melon aphid, Aphis gossypii, Glover, and the black citrus aphid, Toxoptera aurantii, (Fonscolombe). There can be as many as forty-seven generations of aphids per year, but it is only when populations are highest in March and April that they become an economic problem requiring chemical control. Aphids would be a greater problem if it were not for the large complex of biological control agents. Two families of hymenopterous parasites use aphids as their host and a fungus, Empusa fresenii (Now) is an important regulating agent of aphid populations during the warm, humid summer months. There are also a large number of aphid predators found in Florida. Lacewing and syrphid fly larvae as well as adult and larval forms of coccinellid beetles feed on all life stages of aphids.

Biological control is so effective that aphids are seldom a problem except on young trees, where the proportion of new growth to old is high; on 'Temple' orange trees of all ages, where the growth is so slow that high populations of aphids develop before the leaves mature; and more recently on mature trees, where mechanical pruning has stimulated a great amount of new growth. Injury to citrus results from aphid feeding on the young, tender "flush" growth. This feeding results in curled and wilted leaves. These permanently distorted leaves are photosynthetically inefficient. Honeydew secreted by the aphid populations also provides a substrate for the growth of a sooty mold fungus, which also reduces photosynthetic efficiency.



High population levels can result in stunted growth and delay initial fruit production. Feeding on 'Temple' leaves results in stunted growth even with mature trees due to the prolonged growth period (Fasulo and Knapp, 1987).

Recently, aphids assumed further importance as insect vectors of citrus Tristeza virus (CTV). Tristeza quick decline, a disease caused by (CTV) has recently reached epidemic proportions in south Florida following earlier outbreaks in west and central Florida. Tree loss in excess of 50% has occurred in some plantings. The present Tristeza outbreak is occurring in highly productive areas which have largely escaped damage from recent freezes and which are especially important to the future maintenance of Florida's citrus production. Tristeza is spread in Florida by contaminated propagation and by aphid vectors. All three aphid species found on Florida citrus have demonstrated the ability to transmit CTV (Ferguson and Garnsey, 1987). In the 1940's and early 1950's, citrus plantings in Brazil and Argentina on sour orange rootstock were destroyed by Tristeza quick decline. Recently the brown citrus aphid, Toxoptera citricida (Kirkaldy), the most efficient aphid vector of CTV, has been reported as far north as Honduras. The introduction of this vector into Florida would create the potential for more extensive and rapid loss of citrus (Brlansky et al., 1986). Tristeza currently poses a significant hazard to the citrus industry and while vector control is not by itself adequate to prevent this disease spread, this practice may be utilized to slow CTV spread and allow time for additional research.

### Oxydemeton-methyl Usage

The potential acreage of non-bearing trees which could require aphid control is 200,000 acres, as replanting continues during freeze recovery. The total bearing acreage of 'Temple' oranges prior to the freezes was 17,102 with a current acreage of 9,942 (Fla. Ag. Stat. Ser., 1988). It is anticipated that the total acreage will again reach 15,-17,000 acres (Table 2).

Table 2. Potential Use patterns of oxydemeton-methyl on Florida citrus.

No. acres treated <sup>a</sup>	Potential acres pounds a.i.	Total potential pests	Target pest
889,401	215,000	265,000	Aphids

<sup>a</sup>Assumes all nonbearing acreage and all 'Temple' acreage requires treatment, does not include mechanically pruned trees nor use in CTV groves.

Oxydemeton-methyl 2 SC is recommended by the University of Florida at the rate of 5.0 pints formulated product per 500 gallons based on a dilute spray. This dilute spray ranges from 500 to 1500 gallons per acre on mature trees depending upon tree height. Aerial application is also effective and recommended. The percentage of ground versus aerial application is not available. The cost per pound of active ingredient averages \$6.88 for ODM. The per acre cost for material for ODM at five pints per acre is \$8.60 (Table 3).

Table 3. Alternative chemical to oxydemeton-methyl for aphid control on Florida citrus

Chemical	Cost (\$/A)	Cost of application (\$/A)		No. Appl./ Season	Total cost (\$)
		Ground	Air		
oxydem.-methyl	8.60	22.80	6.00	1	31.40-14.00
dimethoate	15.42	22.80	6.00	2	76.64-42.82

The average per acre cost of application is \$22.80 by ground (500 gallons water per acre); \$3.88 or \$4.33 per acre fixed wing aerial application (5 or 10 gallons water per acre); or \$4.50 or \$9.37 per acre helicopter application (5 or 10 gallons water per acre). There is a 2 day worker re-entry period, seven-days-to-harvest interval following treatment, and a limit of two ODM applications per crop season. The material is listed in the Florida recommendations as being moderately toxic to honey bees (Do not apply while bees are actively foraging) (Knapp et al., 1989).

The harvest season for 'Temple' oranges occurs from January through March. Thus the end of the harvest season coincides with the normal bloom period and spring flush of new growth. The treatment to harvest interval, worker re-entry period, and honey bee toxicity level are all very important considerations taken into account before recommending a material for aphid control on the spring flush of 'Temple' orange growth.

The only recommended chemical alternative to ODM is dimethoate, which is marketed as Dimethoate 2.67EC and Cygon 4EC and used at rates of 2.5 to 5.0 pints and 4.0 pints per 500 gallons dilute sprays, respectively. Dimethoate has a four day worker re-entry period; 15 to 45-days-to-harvest interval following treatment (dependent upon rate); it is highly toxic to honey bees (will kill bees for 24 hours after application); and it is limited to two applications per growing season (Knapp, et al. 1989). Dimethoate's short residual activity necessitates two applications to achieve control equivalent to a single ODM application (Brooks, 1968). The cost per pound of active ingredient averages \$6.88 for ODM and \$7.71 for dimethoate. One application of dimethoate at four pints per acre of the 4EC formulation would be \$15.42 (Table 3).

EPA's estimate regarding worker exposure for ground application to citrus; i.e., 8.5 hours/day, one application/year over two consecutive days is reasonable. The figure of 2.6 mg/kg/day is based on surrogate data but whatever the actual exposure, it can be reduced if state of the art protective clothing is required. Also, that percentage of acres treated by air is not addressed.

Oxydemeton-methyl is the material of choice when chemical control of aphids is required on Florida citrus. This systemic product gives 2-3 weeks control, which is usually sufficient to protect a flush of growth until it matures and is no longer susceptible to aphid attack. Contact materials, such as Dimethoate, give quick knockdown, but their short residual action often results in the need for a second application.





## Oxydemeton-methyl Use on Brambles

Rick Weires  
New York Agriculture Extension Service

Oxydemeton-methyl (ODM) is presently registered for aphid and mite control on both raspberries and blackberries nationally. Most state Cooperative Extension Recommendations do not make a distinction between red raspberries, black raspberries, dewberries, and blackberries, but rather lump the latter into the category of brambles or caneberries for purposes of listing cultural practices, pest problems, materials recommended for control of pest problems, rates of materials, and timing of applications for pest control problems (Hull, et al. 1987, Pritts and Wilcox, 1987). Up-to date figures on bramble acreage or production are not reported by the various state or national crop reporting services (Anon., 1986), but approximately 3,360 acres of brambles were estimated to be grown commercially in the 15 states East of the Mississippi river, while 11,000 acres were estimated to be grown West of the Mississippi, according to respondents replying to a November 1988 NAPIAP survey form (Willson and Straub, 1988) or to follow-up phone calls made by NAPIAP team members. Raspberries comprised approximately 75% of this acreage while blackberries or other caneberries comprised the remainder. Raspberries tended to be grown in cool northern climates, while blackberries predominated in warm southern climates.

Historically small fruit production, including bramble cultivation, played a much larger role in the farm economy. Small fruits lost ground, mostly to tree fruit production, starting in the early 30's as child labor laws, poor returns, a reduced export market in England and other European nations, and changing farm practices saw the advent of more specialized farming efforts assume greater importance. Increased abilities to store apples year round led to greater specialization in this phase of fruit-growing to the demise of the more perishable small fruits sector. Ourecky (1969) detailed the problems of the blackberry industry in New York state in the following scenario: "Though once an important small fruit crop in New York, today it is nearly impossible to obtain fresh blackberries for eating or cooking. The decline in production maybe attributed to distribution of sterile clones instead of good varieties, tarnished plant bug damage, and labor problems."

In recent years, however, there has developed a renewed interest in the reduction of small fruits as a result of increased urbanization, reduced tree fruit profitability, and increased direct marketing (Castaldi, 1987). The renewed interest in small fruits, including brambles, also stems from the fact that better plants are available through the use of tissue-culture techniques (Braun, 1986). Thus growers can obtain healthy, virus-free plants of the latest most recently developed cultivars suited to their own unique markets or growing conditions. Since it is estimated that over 90% of the small fruit sold is through Pick Your Own (PYO) or roadside marketing stands, the economic aspects of such marketing strategies makes bramble production a very favorable option.

Castaldi (1987) estimated net establishment costs for raspberries of \$6,500.00/acre over the five year period required to achieve full production. For the remaining 15 years the plots would remain in production, yields should average approximately 5,000 quarts/acre and net revenue approximately \$6,000.00/acre with total yearly production costs (both fixed and variable) of approximately \$4,000.00/acre. In general, Castaldi found the profitability of commercially harvested raspberries to be slightly better than PYO operations, but this was a direct effect of local labor costs which of course are quite unstable. A typical farm, representative of that found in the Castaldi study consisted of approximately 200 acres of which 185 acres would be planted to tree fruits, while 15 acres would be equally divided between strawberries, blueberries, and raspberries. In other areas small fruit production is often maintained in concert with vegetable production and total acreage may be more equally divided between small fruits and vegetables. Bramble production on the West Coast is utilized more for processing, [acreages] are much larger, and yields generally higher.



Prices reported for brambles grown on the West Coast reflected processing prices and averaged \$.52/lb, while yields were reported to average 6400 lb/acre, giving a per acre value for the fruit of \$3,328.00. Prices reported for East Coast fruit reflected the fact that probably 90% of the fruit was sold retail on the farm. Reported yields averaged approximately 3,000 lb/acre, crop value averaged \$2.00/lb, for a per acre fruit value of \$6,000.00. Adding together the west coast (\$36,608,000.00) and east coast (\$20,160,000.00) fruit values gives an approximate value of \$56,768,000.00 for the bramble crops grown in the U.S.

In addition to the commercial bramble industry growing fruit for fresh or processing purposes, there exists a much smaller (acreage-wise) nursery industry devoted to the growing of bramble plants for sale to other nurseries, commercial small fruit growers, and/or homeowners. Several of these nurseries ship the tissue-cultured, virus-free, plants of the newest, most disease-resistant cultivars available, not only to markets in the U.S., but also to many foreign countries which depend on these plants for their industries survival. A typical nursery will grow these plants at densities of from 30,000-50,000 plants/acre. The value of such plants ranges from \$.08-1.00 depending upon whether they are sold to other nurseries, commercial growers, or directly to the homeowner market (Marvin Pritts, personal communication). At an average value of \$.25/plant a typical acre would gross \$7500.00-12,500.00 making it a very valuable commodity. The continued profitability and survival of this specialized industry depends upon the continued availability of effective chemicals for use in controlling aphids which can vector viruses into the concentrated nursery plantings. This requirement (virus vector control) may lessen in the future as aphid-resistant germplasm (Kennedy et al., 1973; Kennedy and Schaefers, 1974; Brodel and Schaefers, 1980) is incorporated into commercially acceptable bramble cultivars (Goulart, 1986).

Over 31 insect and mite pests of brambles have been reported (Slingerland and Crosby, 1914) of which approximately 15 have achieved major pest status at one time or another depending upon the area or species of bramble grown (Slingerland and Crosby, 1914; Mills and Dewey, 1934; Colby et al., 1940; Smith, 1942; Antonelli, et al. 1988). Prior to the use of the synthetic insecticides, certain of these pests were the limiting factor in the cultivation of some bramble crops in rather extensive areas (Daniel, 1928). Most state recommendations presently list from six to 13 major insect or mite pests of brambles (Hull, et al. 1987; Agnello, 1987; Sorenson et al., 1987; Scheer, et al., 1988), including: aphids, e.g., the raspberry aphid, Amphorophora agathonica; the raspberry cane borer, Oberea bimaculata (Olivier); the raspberry crown borer, Pennisetia marginata (Harris); the eastern raspberry fruitworm, Byturus rubi Barber; the raspberry sawfly, Monophadnoides geniculatus (Hartig); the raspberry cane maggot, Pegomya rubivora (Coquillett); the raspberry budmoth, Lampronia rubiella (Bjerkander); The potato leafhopper, Empoasca fabae (Harris); a sap beetle, Glischrochilus quadrisignatus; the tarnished plant bug, Lygus lineolaris (Palisot de Beauvois); tree crickets, e.g., the blackhorned tree cricket, Oecanthus nigricornis Walker; the two spotted spider mite, Tetranychus urticae Koch; psyllids, thrips, the Japanese beetle, Popillia japonica Newman; and leafrollers, e.g., the raspberry leafroller, Olethreutes permundana (Clemens). In addition to the aforementioned arthropod pests, there are more than ten disease (fungal, bacterial or viral) pests of brambles (Hull, et al., 1987; Mills and Dewey, 1934), at least two of which (the raspberry mosaic virus complex and the raspberry leaf curl virus) are vectored by aphids (Travis and Breth, 1987).

The increased interest in small fruit production has prompted several states to develop integrated pest management programs (Travis et al., 1984; Kovach et al., 1988) and conduct surveys for the major problems associated with small fruit production (Goulart, 1986). Such programs typically placed most emphasis on strawberries, while brambles were given cursory inspection (Kovach et al., 1988). Surveys of bramble growers and their plantings in several Eastern states indicated yields were about 1/2 what would be expected; diseases, especially viruses and phytophthora, greatly reduced yields and contributed to the gradual decline of the plantings; poor post harvest fruit longevity was a severe limiting factor; and aphids and mites were the most common arthropod pests noted (Travis et al., 1984; Goulart, 1986).

The recent interest in small fruits has spurred interest in looking more closely at yield relationships and bramble pests. In recently conducted experiments in Geneva New York workers there found significant negative relationships between previous tarnished plant bug densities and the berry yield of infested canes (Spangler and Agnello, 1989). Losses from tarnished plant bug occurred in the bramble fruits as a result of puncturing the fruit itself, or from growth deformities referred to as "button berries" which was similar to damage from tarnished plant bug incurred by strawberries. Similar studies conducted on strawberries reported losses of \$3,700.00/acre due to tarnished plant bug during a season in which nymphal development was synchronous with that of the plants (Schaefer, 1980). This research is continuing and includes work on sampling methods, etc., which will be used in developing a bramble pest management program.

### Oxydemeton-methyl Usage

Presently, from survey respondents' (Willson and Straub, 1988) it is estimated that 2,111 acres of brambles receive an average of one spray, resulting in a total usage of 716 lb ai. of oxydemeton-methyl per season in the U.S. (table 4). The rates of ODM reported varied from 0.2 to 0.4 lb ai/acre with 0.25 being the most common rate. Costs of ODM (per lb ai) ranged from \$10.25 to \$26.00. Per acre total costs of one application ranged from \$9.75 to \$31.00. Application costs per acre (which were included in the [preceeding costs] ) ranged from \$5.00 to \$25.00. Fifty percent of the respondents indicated that the application costs were intrinsic to the operation (i.e. the grower would be applying another material as part of the operation at the same time).

Table 4. Use of oxydemeton-methyl on brambles in the United States\*

State	No. acres grown	No. acres treated	oxydemeton-methyl use (lbs ai)	target pest
New York	1,000	50	12.5	aphids, mites
New Jersey	250	12	3.0	aphids, mites
New Hampshire	150	22	4.4	aphids, mites
Maine	110	5	2.0	aphids, mites
Pennsylvania	600	120	30.0	aphids, mites
North Carolina	250	150	37.5	blackberry psyllid
Michigan	1,000	200	50.0	aphids, mites
Washington	3,600	72	21.6	aphids
Oregon	7,400	1,480	555.0	aphids
TOTAL	14,360	2,111	716.0	

\*Source: NAPIAP survey form (Willson and Straub, 1988).

### Alternative Pest Management

Chemical alternatives to ODM include five synthetic insecticides and/or miticides registered for use on blackberries, seven registered for use on raspberries, three on Boysenberries, and two on dewberries (Anonymous, 1989a). The seven, which included all bramble registrations, were diazinon, malathion, parathion, phosdrin, carbaryl, azinphosmethyl, and disulfoton. Disulfoton is presently registered for use on non-bearing bramble nursery stock only. The



remainder of the registered materials have been, are, or soon will undergo this Special Review process, to determine whether or not such registrations will be maintained or dropped (Table 5).

Table 5. Alternative chemicals to oxydemeton-methyl for aphid or mite control on bramble crops

Chemical	Aphids	Mites	Rate	PHI	Comments
diazinon	WA,OR,ID,MI		1.0	7	not near bloom non-bearing only
disulfoton	NY		7.5		
devinphos			0.125-0.33	3	
azinphosmethyl	WA,OR,ID PA,NC		0.3-0.5	14	
malathion	WA,OR,ID PA,NC		1.5-2.0	1	
carbaryl	NC		1.0-2.0	7	
parathion	MI		0.6		

Considerable differences were noted between states as to which of the materials are recommended and for what pest(s). Almost all state recommendations indicated raspberry plantings should be sprayed with aphicides for control of aphids, which vector raspberry mosaic and raspberry leaf curl (Hull et al., 1987; Pritts et al., 1986). New York, however, only recommends disulfoton (in non-bearing nursery stock) for aphid control (Pritts and Wilcox, 1986), while Michigan lists Diazinon, malathion, and parathion as suggested chemicals for aphid control (Hull et al., 1987). North Carolina includes aphids with all other insect pests, and thus lists azinphosmethyl, malathion, carbaryl, and ODM as suggested materials (Sorenson, et al., 1988).

Unfortunately, current efficacy data for presently registered materials is not available. A search of all small fruits testing results was conducted by examining all of the small fruit insecticide trials reported in Insecticide and Acaricide Tests (published by the Entomological Society of America). The only trial found evaluating insect control on any bramble crop was a 1987 trial on raspberries evaluating the field and bioassay performance of two pyrethroids (not registered for use) and carbaryl for control of Japanese beetle and picnic beetles (Williams and Fickle, 1988). Earlier efficacy tests found that some of the granular systemic materials were more effective than the foliar applied systemics, e.g., aldicarb was the most effective material at providing season-long aphid control (Schaefer, 1968). Carbofuran was the most effective of the foliar applied systemics, while ODM was the most effective of the materials tested at that time which remain registered for use today (Schaefer, 1968) (none of the granular systemics [except disulfoton] nor carbofuran are registered on brambles). The importance of a management program utilizing an effective aphicide such as ODM was regarded as a necessity in the production of virus-free nursery stock by nurserymen (Schaefer, 1967).

Most state recommendations as well as respondents to the PIAP survey (Willson and Straub, 1988) recommended mite control on brambles as very important, but most recommendations (Hull et al., 1987; Sorenson, 1988; Pritts and Wilcox, 1986) list dicofol alone as the material to use for control. Only New York state in its "Redbook" lists ODM as an optional material to use for mite control (Agnello, 1987). Respondents to the PIAP survey indicated that dicofol was the principle effective option to ODM for mite control and that from 1% to 100% of the bramble acreage received a miticide application each season (average 30%) depending upon the state surveyed. In addition, respondents listed potential resistance problems being a factor with all options listed for mite control, including dicofol. The most

recent dicofol labels contain no mention regarding use on bramble crops (Anonymous, 1989a) and a check with the company (Dr. Mike Covey, personal communication) indicated that the registrant dropped minor use labels, such as brambles, to permit its continued registration on other crops.

A recent survey of the potential for biological control on crops grown in the state of Massachusetts concluded: "In general it appears that little or no serious attention has been given to the biological control of raspberry pests, in part perhaps because of the crop's minor status economically." (Van Driesche and Hauschild, 1987). The authors pointed out that a pesticide resistance problem exists with respect to two-spotted spider mites on strawberries and recommended that a predator-based control system be developed. They further noted that some efforts to provide biological control of the tarnished plant bug has occurred on other crops through parasite introductions, and recommended that the role of tarnished plant bug natural enemies be studied since it is a major pest on both raspberries and strawberries (Van Driesche and Hauschild, 1987).

### **Potential for Pest Resistance**

Presently little is being done in the way of pesticide resistance management on brambles. Survey respondents (Willson and Straub, 1988) indicated that mites were a major concern and that dicofol-resistant strains may be present in some areas. Dicofol-resistant mites have been reported from a range of crops at several locations, but resistance management programs to minimize the problem have been most active on cotton and apples (Dennehy et al., 1988). Resistance to dicofol can be monitored with discriminating-concentration bioassays (Dennehy et al., 1983), while a practitioner-assessable bioassay (Dennehy et al., 1987) allows pest management personnel to assess the frequency of dicofol-resistant mites in the field and make control decisions based on this frequency. A key to managing the dicofol-resistance problem is the ability to be able to utilize alternative miticides or control methods while removing the selective pressure (i.e. the dicofol applications) on the population. Removing such selective pressure on a mite population should allow that population to revert back to susceptibility. Thus alternating materials based on the frequency of resistant genotypes should allow for the continued usage of such materials as well as permitting the development of integrated mite control programs utilizing predators, which may be affected differentially by the materials use.

Pesticide resistance is a factor in the continued recommendation of ODM usage on blackberries in North Carolina and Pennsylvania, where it is the only material which gives satisfactory control of a psyllid, *Trioza tripunctata* (Fitch) (K. Sorenson, personal comm.; Goulart, 1989). The psyllid migrates from its alternate host (conifers) in the spring to the blackberry canes where it commences feeding. The new shoots and leaves are distorted or stunted and as a result will not bear normal berries. Sorenson estimates that the loss of ODM in North Carolina bramble production would result in approximately a 20% crop loss each year, due to damage from the psyllid. Application practices and worker exposure. Survey respondents (Willson and Straub, 1988) as well as interviews with growers and Extension specialists indicated that almost all applications of ODM were made by ground application using tractor pulled sprayers. Vegetable growers tended to use boom type applicators more common to their vegetable operations, while fruit growers were more likely to use airblast type sprayers used in spraying fruit trees. Most operators used delivery rates of from 50 to 200 gal per acre, with 200 gal per acre generally used as the dilute rate on which to base materials and concentrations (Hull et al., 1987). Applicator exposure was reduced by wearing protective clothing, driving in an enclosed tractor cab, or using one of the several air filter-pressurization units which were developed (using ODM as a test chemical) to remove pesticides from the air entering the tractor cab (Taschenberg, et al., 1975). Cultural practices associated with brambles also tend to reduce worker exposure to pesticides since the major tasks of pruning and thinning the canes occurs during March and April while removing floricanes after fruiting occurs during September and October, thus workers are not in the field except during harvest in the summer (Pritts et al., 1986). Exposure to workers, PYO personnel, or others involved with the harvest



is minimized by following the strict Days-to-harvest Intervals, which for ODM is seven days for both raspberries and blackberries (Agnello, 1987).

## **Summary and Conclusions**

The need for the continued registration of oxydemeton-methyl for control of bramble insect and mite pests appears to grow more critical as alternative chemicals are withdrawn and pest resistance to presently available alternatives increases. The loss of dicofol as the only alternative for mite control to ODM in most state recommendations may be critical in coming years. Weather patterns play a major factor in the outbreak of mite populations, and there are those who are predicting major changes in the weather patterns of the future, with drought conditions a major consequence. Drought conditions are highly favorable to certain mite pests, such as the two spotted spider mite, which could emerge as a major bramble pest under such conditions. The continued registration of ODM for established bramble resistance problems, such as psyllids on blackberries, is also of vital concern. The lack of current pesticidal efficacy data with respect to pests, such as aphids and the tarnished plant bug, is also of concern since recent research and earlier observations on the plant bug (Spangler and Agnello, 1989; Ourecky, 1969) as well as recent surveys of virus incidence (Goulart, 1986), have indicated significant yield reductions may be occurring due to these pests. Further research is needed on damage/yield relationships and sampling methodology for mite, aphid, and plant bug infestations on brambles, so that much needed economic threshold levels can be established for these pests thereby furthering the development of fledgling integrated pest management programs being established. In the interim the continued registration and testing of ODM as a proven and/or potentially beneficial tool in the management of such pests remains a high priority.

## Oxydemeton-methyl Use on Pears

H. Y. Forsythe, Jr.  
University of Maine

There is currently a federal label to allow use of oxydemeton-methyl (ODM) for aphids and mites on pears in all states. No more than one application at 1 pt/100 gal of water is permitted per season, and ODM should not be applied within 30 days of harvest. Associated with ODM is a 48-hour reentry period (Anonymous, 1989a).

In a survey of 23 states that grow at least some acreage of pears, 22 states reported that ODM was not recommended and/or used on pears (Willson and Straub, 1988). The only state reporting usage was CA where nine growers each applied one application of ODM to a total of 105 acres which is 0.4 percent of the total pear acreage of 26,000 acres grown in CA (Table 6).

Table 6. Oxydemeton-methyl usage on pears in 1986\*

State	No. acres grown	Yield	Value	No. acres treated
		(tons)	(\$)	
California	26,000	294,000	232	105
Washington	25,800	266,000	274	0
Oregon	18,605	167,000	304	0
New York	3,400	19,000	210	0
Michigan	1,700	11,000	233	0
Pennsylvania	1,000	3,000	317	0
Connecticut	200	1,600	485	0

\*Source: Agricultural Statistics Handbook (Anonymous, 1986) and survey respondents.

The primary target pests for ODM in CA are aphids, most likely apple aphids and or spirea aphids. High populations of aphids can cause leaf curling, reduction of terminal and water sprout growth, and possibly reduction of fruit size. Aphids produce honeydew which falls onto foliage and fruit and is an excellent growth medium for black sooty fungus which, in turn, can cause fruit discoloration. It has been suggested, however, that reduction of terminal and water sprout growth may be advantageous on mature trees (Brunner & Howitt, 1981; Madsen & Barnes, 1959).

Although ODM is also registered for control of mites on pears, and European red mite and other spider mites can be a serious problem, no ODM is presently being used as a miticide. Spider mites, primarily European red and two-spotted spider mites, can cause serious problems on pears if populations are left uncontrolled. Mites feed on the chlorophyll of the leaves. Leaves can recover if mites are destroyed before the leaves are too badly damaged; but, if too much chlorophyll is withdrawn, the foliage turns bronze or brown and the chlorophyll can never be entirely replaced. Severe leaf browning may result in reduced tree growth, small fruit, reduced fruit set the following year, and even leaf drop. The eriophyid pear rust mite feeds not only on the leaves, but also on the surface of the pear fruits. Their feeding causes a russetting on the outside of the pear, making the fruit unacceptable for most fresh market sales and interfering with processing procedures (Brunner & Howitt, 1981; Madsen & Barnes,



1959). The label for ODM lists mites as target pests but does not specify spider mites or eriophyids; it is assumed that the former group is the primary target.

One state, MD, suggested that ODM could be used to suppress pear psylla populations, an insect that can be very injurious to pears and which has developed resistance to a number of insecticides. If left uncontrolled, the pear psylla extracts water and nutrients from the leaves, thus reducing tree growth and possibly influencing fruit set the following year. Excessive feeding can also reduce pear fruit size. Psylla nymphs also secrete honeydew which results in a situation as described for the aphids. In addition, the psylla injects a toxin with its saliva, which is responsible for "psylla shock", an adverse response of the pear tree to feeding by large psylla populations. This insect is also capable of causing "quick" and "slow" pear declines, conditions which eventually could kill the trees (Brunner & Howitt, 1981; Madsen & Barnes, 1959). However, ODM is not used or recommended for control of psylla, although occasionally some suppression may occur.

## **Pest Management**

In those areas with intensive culture and large acreages of pears, there are some organized integrated pest management (IPM) programs specifically for pears. Although these programs may be aimed primarily at pests such as codling moth and pear psylla, additional monitoring, although maybe to a minor degree, is done for aphids and mites, and in a similar way as carried out on apples (Beers, 1988; Brunner & Howitt, 1981; Jones et al., 1988). Aphids and mites are attacked by a number of natural arthropod enemies, such as lady beetles, predatory mites, some species of fly larvae, lacewings, and braconid wasps (Brunner & Howitt, 1981). Predators and parasites are present in all producing areas and the extent to which they contribute to pest control will vary greatly from area to area and from season to season. Climatic conditions and tree growth stages will also greatly influence the intensity and duration of a pest problem. Therefore, annual and effective control by natural enemies is not considered as a viable alternative to insecticidal control of mites and aphids. As some monitoring is done for the pear psylla and codling moth, supplementary observations may be taken on mites and aphids. Monitoring generally includes observations on the climate, tree growth and natural enemies; recommendations for specific insecticide treatments are determined from these observations.

The preservation of natural enemies by selective use of general insecticides which allow natural enemies to survive, and by altering orchard management practices to provide protective habitats, assists in control of pest arthropods. Subsequently the need for insecticides and miticides may decrease (e.g. Beers, 1988). Although pesticide selection is commonly considered by growers, development of protective habitat is not. No other nonchemical methods of control for either type of pest have been developed or reported to have been used in general orchard practices.

## **Oxydemeton-methyl Usage**

The application of an insecticide or miticide on pears is accomplished by ground equipment, with air-blast sprayers the predominant choice. State recommendations stress that thorough spray coverage of the trees is desirable, if not necessary; commonly 300-400 gallons of pesticide and water-spray mixture, on a dilute basis per acre, is mentioned (e.g. Beers, 1988; Jones et al., 1988). However, more concern is being expressed among the states about the loss of pesticides to off-target areas. One recent practice by some growers, to counter this problem, is the application of sprays according to the tree row-volume concept. Another way which growers attempt to reduce pesticide loss and preserve natural enemies is alternate tree-row spraying. Both methods are described in the recommendations of many states (e.g. Beers, 1988; Jones et al., 1988).

In the use of ODM on pears, human exposure is primarily limited to the applicator. It has been estimated that two acres can be carefully treated in one hour by ground equipment

and one applicator. It has also been estimated that an additional 5-10 minutes of exposure occurs for mixing and loading a spray tank to treat about two acres (J. McCue, person. comm.). In the application of ODM to 105 acres of pears by all pear producers in the country, 61.2 hours of exposure to ODM in a single season are calculated. Direct exposure to ODM is very limited. Applicators operating ground units with enclosed cabs or other enclosed canopies usually wear normal work garments. Others commonly wear a hard hat, laundered overalls, boots, and gloves. Optimally, and less commonly, sprayer operators will be equipped with impervious rainwear and respirators with or without eye protection. This protective clothing is worn during the application of a pesticide, as well as during the time liquid formulations of ODM are hand-poured, measured, and introduced into the spray tank. Although requirements vary from state to state, all private and commercial applicators must be licensed to use restricted materials, of which ODM is one; licensing generally requires a rather thorough knowledge of pesticides and safety procedures. Exposure of the applicator to ODM is estimated to be very minimal.

In regards to exposure by other workers in the orchards, this is again minimal. Generally, the only people involved are IPM scouts and pickers. IPM scouts are generally aware of, or made cognizant of, the times of pesticide applications and reentry periods before entering orchards. ODM has a reentry period of 48 hours, and adequate protective clothing is worn by scouts if orchard visits are essential within that time-frame. Scouts are not permitted to be present in the orchard at the time of treatment and, when present during the post treatment period, they do not have substantial and prolonged contact with any of the treated tree surfaces. Pickers are also prevented from having any exposure to ODM residues; tolerance requirements superimpose a 30-day interval from treatment to harvest. Pickers are essentially not at risk in relation to ODM exposure.

### **Alternative Chemicals**

The chemical alternatives to ODM, as indicated by the survey respondents are listed in Table 7. Three alternatives have been reported for use against aphids and six for mites. Of those used for aphids, dimethoate and endosulfan are as effective as ODM (Willson and Straub, 1988), somewhat similar or lower in mammalian dermal toxicity, and have slightly shorter pre-harvest intervals (28 and 7-21 days, respectively). The relative costs of the alternative chemical treatments are difficult to assess because there appears to be great variability from area to area and among customers or respondents. However, a comparison of average costs per acre seems to indicate that dimethoate costs the same as ODM and the price of endosulfan is twice that of ODM. Although dimethoate would certainly seem to be a viable substitute for ODM and endosulfan a more expensive alternative, there seems to be a definite need for a second choice insecticide like ODM. The label restriction of only one spray of ODM per season might limit its demand by growers as compared to the two or more sprays allowed with the alternative insecticides.

Although ODM has been shown to be highly effective against mites, and these arthropod pests are listed on its label, ODM is not generally considered a highly effective miticide today. Other materials are rated as being better, or at least equal in, efficacy to ODM; these are dicofol (although mite resistance to this compound is currently present in orchards), fenbutatin-oxide, formetanate-hydrochloride, and propargite (Willson and Straub, 1988). All these materials have much lower dermal toxicities to mammals, and shorter pre-harvest intervals (7-14 days) than ODM; however, propargite is limited in its use on pears because it is labelled only on non-bearing trees or for the post-harvest period. The cost of these alternatives (for use during the bearing season) is over 2-3 times the cost of ODM per acre. Since mite problems can occur during the entire season through harvest, and often require two treatments of miticide, it would appear that growers would have to choose the more expensive materials over ODM because of their shorter pre-harvest intervals and label allowances of greater than 1 spray season.



Other insecticides which list aphids as target pests on pears include azinphosmethyl, carbaryl, diazinon, malathion, mevinphos, phosmet, and phosphamidon (Anonymous, 1989a). They are not recommended by the states, most likely because they, except for possibly mevinphos and phosphamidon, are not considered to produce consistently good control (Agnello, 1986; Beers, 1988; Jones et al. 1988). Mites are also included on the labels of diazinon, ethion, malathion, mevinphos, and phosmet.

These materials are viewed as occasionally assisting in suppressing mite populations (Agnello, 1986; Beers, 1988; Jones et al. 1988). A major concern of growers has been the development of resistance to miticides in mite populations, and, more specifically, the potential cross-resistance possible among organophosphate compound, such as ODM and the previously mentioned materials (e. g., Cutright, 1963). Labelled compounds not considered as viable mite control alternatives to ODM, because they are for pre-bloom use only, are superior oil and oxythioquinox. However, their use may assist in reducing the need or frequency of applications of summer materials.

Research data on summer control of the apple aphid can be used as an indication of relative efficacy against aphids on pears (Fisher, 1987; Forsythe, 1966, 1967, 1970; Forsythe & Hall, 1973; Glass & Chapman, 1955). The best and equal control was generally given by dimethoate, endosulfan, and phosphamidon. Lesser control was given by azinphosmethyl, carbaryl, diazinon, malathion, and phosmet; variable efficacy has been recorded for diazinon, ethion, and parathion. Data on European red mite control revealed good and equivalent control by dicofol, dimethoate, and propargite; lesser control was found with ethion (Forsythe, 1966, 1967, 1970). Although tests on azinphosmethyl, diazinon, phosmet, and phosphamidon were not found, it is generally conceded that they are no longer highly effective miticides.

The labels for ODM and alternative insecticides, state recommendations, and user input do not indicate that any chemical listed here adversely affects plant quality or yield. The exception is the warning by NY against the use of propargite on D'Anjou and Comice pear varieties, and by WA against the use of dimethoate on Anjou pear varieties.

The ODM alternatives dimethoate and propargite are under EPA special review; consequently their future availability cannot be assured. It is recommended that the re-registration status of alternate chemicals should be a major consideration in the benefits assessment process.

It should be mentioned that the use of certain chemicals for control of other arthropod pests may alter the status of aphid and mite importance. For example, the use of pyrethroid insecticides to control the pear psylla may reduce the predator populations and allow aphids or mites to become more abundant than usual. However, the application of endosulfan or amitraz for suppression of the psylla may result in aphid or spider mite control, respectively. Some of the alternative miticides will control both the spider mites and the eriophyid pear rust mite, whereas the use of endosulfan for aphids will result in control of the rust mite but not spider mites. Pest management programs generally resolve this type of pesticide selection decision on the basis of pest predator populations present.

## Summary

As far as can be determined, oxydemeton-methyl is not in general use in commercial pear production. Since there are currently effective registered alternatives, the cancellation of ODM for use on pears is expected to have little or no impact on the costs of production, output, or quality of domestic pears.

## Oxydemeton-methyl Use on Plums and Prunes

H. Y. Forsythe, Jr.  
University of Maine

There is currently a federal label to allow use of oxydemeton-methyl (ODM) for aphids and mites on plums and prunes in all states. No more than two applications at 1 pt/100 gal of water each are permitted per season, and ODM should not be applied within 35 days of harvest. The product label for ODM lists a 48-hour reentry period (Mobay Corp., 1989).

In a survey of 25 states that grow at least some acreage of plums and prunes, 23 states reported that ODM was not recommended and/or used on plums and prunes. The only states recommending and reporting usage were CA and OR. In CA seven growers each applied one application of ODM to a total of 317 acres, which is 0.3% of the total plum and prune acreage of 101,400 grown in that state. OR, which reported less than 1800 acres treated, does not recommend ODM in its Spray Guide (Table 8).

Table 8. Usage of oxydemeton-methyl on plums and prunes in 1986\*

State	No. acres grown	Yield	Value	No. acres treated
		(tons)	(\$)	
California	101,400	152,000 (plums)	657 (plums)	317
Oregon	4,205	26,000	155	1,800
Michigan	3,900	11,000	243	0
Washington	2,310	9,100	366	0
Idaho	1,500	5,000	477	0
New York	1,000	1,800	440	0

\*Source: Agricultural Statistics Handbook (Anonymous, 1986) and survey respondents.

The primary target pests for ODM in CA are the prune leafhopper and aphids, most likely the leaf curl plum aphid and the mealy plum aphid. Treatment of the aforementioned aphid species is also recommended in OR. High populations of leafhoppers and aphids can cause leaf curling, reduction of terminal and water sprout growth, and possibly reduction of fruit size. They produce honeydew which falls onto foliage and fruit and is an excellent growth medium for black sooty fungus which, in turn, can cause fruit cracking. It has been suggested, however, that reduction of terminal and water sprout growth may be advantageous on mature trees (Brunner & Howitt, 1981; Dustan & Davidson, 1973).

Although ODM is also registered for control of mites on plums and prunes, and European red mite and other spider mites can be a serious problem, no ODM is presently being used as a miticide. The spider mites, primarily European red and two-spotted spider mites, can cause serious problems on plums and prunes if the populations are left uncontrolled. Mites feed on the chlorophyll of the leaves. Leaves can recover if mites are destroyed before the leaves are too badly damaged; but, if too much chlorophyll is withdrawn, the foliage turns bronze or brown and the chlorophyll can never be entirely replaced. Severe leaf browning may result in reduced tree growth, small fruit, reduced fruit set the following year, and even leaf drop. The eriophyid plum rust mite also feeds on the leaves and can cause leaf injury (Brunner & Howitt, 1981;



Dustan & Davidson, 1973). The label for ODM lists mites as target pests but does not specify spider mites or eriophyids; it is assumed that the former group is the primary target.

## **Pest Management**

In those areas with intensive culture and large acreages of plums and prunes, there are some organized integrated pest management (IPM) programs specifically for tree fruits; NY reported that none are carried out on plums and prunes in that state. These programs may be aimed primarily at pests such as plum curculio and apple maggot; additional monitoring, although to a minor degree, is done for leafhoppers, aphids and mites, and in a similar way as carried out on apples (Beers, 1988; Brunner & Howitt, 1981; Jones et al. 1988).

Aphids, leafhoppers, and mites are attacked by a number of natural arthropod enemies, such as lady beetles, predatory mites, some species of fly larvae, lacewings, and braconid wasps (Brunner & Howitt, 1981). Predators and parasites are present in all producing areas; the extent to which they contribute to pest control will vary greatly from area to area and from season to season. Climatic conditions and tree growth stages will also greatly influence the intensity and duration of a pest problem. Therefore, annual and effective control by natural enemies is not considered a viable alternative to insecticidal control of these pests. As some monitoring is done for the plum curculio and apple maggot, supplementary observations may be taken on mites, leafhoppers, and aphids. Monitoring generally includes observations on the climate, tree growth and natural enemies; recommendations for specific insecticide treatments are determined from these observations.

The preservation of natural enemies by selective use of general insecticides which allow natural enemies to survive, and by altering orchard management practices, to provide protective habitats, assists in control of pest arthropods. Subsequently the need for insecticides and miticides may decrease (e. g., Beers, 1988). Although pesticides selection is commonly considered by growers, development of protective habitats is not. No other nonchemical methods of control for these pests have been developed or reported to have been used in general orchard practices.

## **Oxydemeton-methyl Usage**

The application of an insecticide or miticide on plums and prunes is accomplished by ground equipment, with air-blast sprayers the predominant choice. State recommendations stress that thorough spray coverage of the trees is desirable, if not necessary; commonly 300-400 gallons of pesticide and water-spray mixture, on a dilute basis per acre, is mentioned (e. g. Beers, 1988; Jones et al. 1988). However, more concern is being expressed among the states about the loss of pesticides to off-target areas. One recent practice by some growers, to counter this problem is the application of spray according to tree row-volume. Another way which growers attempt to reduce pesticide loss and to preserve natural enemies is alternate tree-row spraying. Both methods are described in the recommendations of many states (e.g., Beers, 1988; Jones et al. 1988).

In the use of ODM on plums and prunes, human exposure is primarily limited to the applicator. It has been estimated that two acres can be treated in one hour by ground equipment and one applicator. It has been estimated that an additional 5-10 minutes of exposure occurs for mixing and loading a spray tank to treat about two acres (J. McCue, pers. comm.). In the application of ODM by all plum and prune producers in the country, about 1,235 hours of exposure to ODM in a single season are calculated. Direct exposure to ODM is very limited. Applicators operating ground units with enclosed cabs or other canopy protections usually wear normal work garments. Others commonly wear a hard hat, laundered coveralls, boots, and gloves. Optimally, and less commonly, sprayer operators will be equipped with impervious rainwear and respirators with or without eye protection. This protective clothing is worn during the application of a pesticide as well as during the time liquid formulations of ODM are hand-poured, measured and introduced into the spray tank. Although requirements vary

from state to state, all private and commercial applicators must be licensed to use restricted materials such as ODM. Licensing generally requires a rather thorough knowledge of pesticides and safety procedures. Exposure of the applicator to ODM is estimated to be very minimal.

In regards to exposure by other workers in the orchards, this is again minimal. Generally, the only people involved are IPM scouts and pickers. IPM scouts are generally aware of, or made cognizant of, the times of pesticide applications and reentry periods before entering orchards. ODM has a reentry period of 48 hours, and adequate protective clothing is worn by scouts if orchard visits are essential within that time-frame. Scouts are not permitted to be present in the orchard at the time of treatment and, when present during the post treatment period, they do not have substantial and prolonged contact with any of the treated tree surfaces. Pickers are also prevented from having any exposure to ODM residues; tolerance requirements superimpose a 35-day interval from treatment to harvest. Pickers are essentially not at risk in relation to ODM exposure.

### **Alternative Chemicals**

The summer chemical alternatives to ODM, as indicated by the responding states, are listed in Table 9. Four alternatives have been reported for use against aphids and five for mites. Of those used for aphids, endosulfan and possibly parathion appear to be as effective as ODM (Willson and Straub, 1988); however, only endosulfan is similar or lower in mammalian dermal toxicity. Both have slightly shorter pre-harvest intervals (7 and 14 days, for endosulfan and parathion, respectively). The relative costs of the alternative chemical treatments are difficult to assess because there appears to be great variability from area to area and among customers or respondents. However, a comparison of average costs per acre seems to indicate that parathion costs half as much as ODM and the price of endosulfan is twice that of ODM. Although parathion would seem to be a viable substitute for ODM, except for its high mammalian toxicity, and endosulfan a more expensive alternative, there seems to be a definite need for a second choice insecticide like ODM.

Although ODM has been shown to be highly effective against mites, and this arthropod pest is listed on its label, ODM is not generally considered a highly effective miticide today. Other materials are rated as being better, or at least equal, in efficacy to ODM; these are dicofol, fenbutatin-oxide, formetanate-hydrochloride, and propargite (Willson and Straub, 1988). Note should be made that plums and prunes are not listed on a newer label for dicofol (Anonymous, 1989a). All of these materials have much lower dermal toxicities to mammals, and shorter pre-harvest intervals (7-14 days). The cost of these alternatives is over 2-3 times the cost of ODM per acre. Since mite problems can occur during the entire season, and often require two treatments of a miticide, it would appear that growers would have to choose the more expensive materials over ODM because of their shorter pre-harvest intervals.

Other insecticides which list aphids as target pests on plums and prunes include azinphosmethyl, carbaryl, fenvalerate, and mevinphos (Anonymous, 1989a). They are not recommended because they are not considered to produce consistently good control (Agnello, 1986; Beers, 1988; Jones et al. 1988; Olson et al. 1987). Mites are also included on the labels of diazinon, mevinphos, and phosmet. These materials are viewed as occasionally assisting in suppressing mite populations (Agnello, 1986; Beers, 1988; Jones et al. 1988). A major concern of growers has been the development of resistance to miticides in mite populations, and, more specifically, the cross-resistance very prominent among organophosphate compounds such as ODM and others listed above (Cutright, 1963). Other labelled compounds not considered as viable alternatives to ODM because they are for use only in the pre-bloom period are superior oil and chlorpyrifos for aphids and mites, oxythioquinox for mites, and methidathion for aphids. However, their use may assist in reducing the need or frequency of applications of summer materials.

Research data on summer control of the apple aphid can be used as an indication of relative efficacy against aphids on plums and prunes (Fisher, 1987; Forsythe, 1966, 1967,



1970; Forsythe & Hall, 1973; Glass & Chapman, 1955). The best or equal control was generally found with dimethoate, endosulfan, and phosphamidon. Lesser control was obtained with azinphosmethyl, carbaryl, diazinon, malathion, and phosmet.

Variable efficacy has been recorded for diazinon, ethion, and parathion. Data on European red mite control revealed good or equivalent control with dicofol, dimethoate, and propargite, but lesser with ethion (Forsythe, 1966, 1967, 1970). Although tests on azinphosmethyl, diazinon, phosmet, and phosphamidon were not found, it is generally conceded that they are presently not highly effective miticides.

The labels for ODM and alternative insecticides, state recommendations, and user input do not indicate that any chemical listed here adversely affects plant quality or yield. One alternative of ODM for aphids (parathion) and one for mites (propargite) are under special review by the EPA; consequently their availability to growers cannot be assured. It is recommended that the re-registration status of alternate chemicals should be a major consideration in the benefits assessment process.

It should be mentioned that the use of certain chemicals for control of other arthropod pests may alter the status of aphid and mite importance. For example, the use of pyrethroid insecticides to control the plum curculio may reduce the predator populations and allow aphids or mites to become more abundant than usual. Some of the alternative miticides will control both the spider mites and the eriophyid plum rust mite; the use of endosulfan for aphids will result in control of the rust mite but not spider mites. Pest management programs generally resolve types of pesticide selection, decisions on the basis of pest-predator populations present.

## **Summary**

As far as can be determined, oxydemeton-methyl is not in general use in commercial plum and prune production. Since there are currently effective registered alternatives, the cancellation of ODM for use on plums and prunes is expected to have little or no impact on the cost of production, output, or quality of domestic plums and prunes.

## Oxydemeton-methyl Use on Non-bearing Fruit Crops

Elizabeth H. Beers  
Washington State University

### Introduction

Oxydemeton-methyl (ODM) is currently registered for aphid and mite control on non-bearing apples, apricots, cherries, crab apples, grapes, nectarines, peaches, plums, prunes and quince. The listing for plums and prunes is redundant since they also have bearing labels. The maximum label rate is 1 to 1.5 pints (0.25-0.375 lbs AI) per 100 gallons. It may not be used on trees that will bear fruit within the following 12 months. There is no limit listed on the number of applications per season; the label only specifies that treatment should be repeated as necessary.

Non-bearing fruit is usually defined as trees that have been in the ground for three years or less. The amount of time required for fruit trees to come into bearing varies considerably among species, and also among cultivars within species. For example, apple strains of 'Delicious' may have a significant amount of fruit in their second year under intensive management, whereas 'Northern Spy' may take 8-10 years to produce a crop. On the average, apples bear in the 4th to 5th year. Horticultural practices (rootstock, pruning and training system, plant growth regulators) may also have a significant influence on the year in which the first commercial crop is harvested. Overall, there has been a great deal of emphasis on bringing trees into bearing early in order to recover the initial cost of planting the orchard.

It is difficult to obtain estimates on the acreage of non-bearing fruit. Usually it is lumped in the total acreage for the fruit species. If a fruit tree survey is available, this may be used to estimate the acreage of non-bearing fruit. Recent surveys were available for two states, Washington (1986) and Pennsylvania (1987) (Table 10). The percent of total fruit that is non-bearing varies greatly, from 1.3 to 50%. The variation in stone fruits is the greatest; apples were 8.8 to 10.2%, and pears were 6.4 to 6.5%.

Fruit trees in the nursery may also be classified as non-bearing. The management system for nurseries tends to vary from that of a commercial orchard. This is dictated in part by the economics of nursery tree production. The per acre value of nursery trees is very high. Trees are planted from 4 to 10 inches in the row, with 3-4 feet between rows, with a resulting tree density of 13,120 to 48,400 trees per acre. Each tree has a value of ca. \$3.50 to \$7.00, depending on size, quality, and cultivar (rootstock and scion). A rough estimate of the average value is about \$165,000/acre. It is not difficult to justify expenditures on pesticides to protect such an investment.

In general, the scion part of a nursery tree is allowed one complete growing season before being harvested and sold. The growth achieved during this season is critical to the quality of the tree, and hence the sale price. Indirect pests (ones that affect tree growth in any way), tend to be strictly controlled; the only pests that are not of concern at this stage are direct (fruit-feeding) pests. Both aphids and mites fall into the former category.

The species of mites that commonly affect fruit trees (both bearing and non-bearing) are the European red mite, Panonychus ulmi, two spotted spider mite, Tetranychus urticae, McDaniel spider mite, Tetranychus mcdanieli McGregor, and the apple rust mite, Aculus schlectendali. Mites reduce tree growth by removal of chlorophyll from leaf tissues, thus reducing the tree's photosynthetic capacity.



Table 10. Percentage of fruit acreage that is non-bearing in Pennsylvania and Washington

State	Crop	Unit	Total units	No. units aged 1-3 yrs	% Non-bearing
Washington	Apple	acre	160,980	14,175	9
	Pear	acre	25,750	1,685	6
	Sweet Cherry	acre	13,725	960	7
	Tart Cherry	acre	1,270	635	50
	Peach	acre	2,795	245	9
	Nectarine	acre	1,205	205	17
	Plum/Prune	acre	2,310	405	18
	TOTAL:		208,035	18,310	9
Pennsylvania	Apple	tree	2,439,951	249,211	10
	Pear	tree	125,818	8,077	6
	Sweet Cherry	tree	40,815	3,467	8
	Tart Cherry	tree	217,848	29,487	14
	Peach	tree	871,645	115,498	13
	Nectarine	tree	98,715	30,257	31
	Plum/Prune	tree	25,103	1,901	8
	TOTAL:		3,819,895	437,898	11
	Grape	acre	10,318	141	1

There are several species of aphids that will attack fruit trees, including the apple aphid, Aphis pomi, the rosy apple aphid, Dysaphis plantaginea, and the woolly apple aphid, Eriosoma lanigerum. Unlike mites, aphids are phloem-feeders, and debilitate the tree by removing photosynthate (plant sugars) that has already been produced. In addition, aphid feeding is concentrated on tender, succulent growth, which is characteristic of nursery trees. Heavy populations can distort terminal growth, which would lower the value of the tree. Both A. pomi and D. plantaginea can produce this type of damage. E. lanigerum has very different feeding habits from other aphids. It forms colonies on the roots and on the aerial parts of the tree. Root feeding causes gall formation, which affects the tree's ability to take up nutrients. The aerial colonies are associated with two sites on the tree: wounds, including those caused by pruning, and leaf axils. The colonies associated with wounds tend to keep it from healing, and provide an infection court for perennial canker, a woody tissue disease. Axillary colonies form in mid- to late summer, when aphids are abundant, and cause gall formation. Infestation with E. lanigerum would probably make the trees unsalable.

Twenty-six states responded to the survey on non-bearing fruit. There was some confusion between trees in the nursery and trees planted in an orchard. Based on the type of units used (acres vs. plants) 3 of the respondents were referring specifically to nursery use. In addition, a separate phone survey of nurseries was conducted. These sites will be discussed separately.

Part of the difficulty in discussing non-bearing fruits is that 10 different fruit species are listed on the label, and management and alternative chemicals vary widely between species. The discussion will be slanted heavily toward apples, because they comprise the largest acreage. Another difficulty encountered in the survey is that most respondents assumed that if ODM was not used, alternative chemicals need not be listed. Thus, only four of the respondents listed alternative chemicals.

Oxydemeton-methyl is somewhat unusual in having activity against both mites and aphids. Frequently, acaricides are classed as a separate group of materials. Alternative aphicides and alternative acaricides are discussed separately.

### **Oxydemeton-methyl Usage**

Non-bearing (orchard use): In general, respondents apparently obtained information on oxydemeton-methyl usage by three means: personal knowledge, listing the state's pesticide recommendations, or surveying chemical distributors. Only one state, California, has a published list of pesticide usage. Unfortunately, this report does not distinguish between bearing and non-bearing uses. However, since it lists usage only on pears, plums, and prunes (where it has a bearing label), it is safe to assume that none is used on non-bearing fruits.

Regardless of the source of information, the pattern that emerged was the same: ODM is not used on non-bearing fruit. There may be several reasons for this. First, because it does not have a label for bearing fruit, growers may not be familiar with the product. In general, unless there is a serious problem for which there is no bearing label, they will simply use the same materials that they use on their bearing trees. The other possible reason is that there are alternative chemicals available.

### **Alternative Pest Management**

There are a number of alternative aphicides (Table 11), although the status of these is questionable. Some are used only on certain crop species, and some are only used at specific times of the season. In Washington, most fruit trees receive a delayed dormant application of oil plus an organophosphate insecticide. Among other pests, this spray is effective against the overwintering aphid eggs of certain species.

Some of these materials, however, would not be recommended against the motile stages later in the season. The chemicals available for this usage are more limited. Dimethoate, phosphamidon, and endosulfan are materials typically used on Washington apples as specific aphicides; methomyl and the pyrethroids are listed as having fair to good activity against aphids, but their primary use is against other (direct) pests and the aphid control is a side benefit. The latter materials thus would not be good candidate materials for non-bearing fruit.

### **Pesticide Resistance**

Resistance to pesticides is a matter of grave concern to tree fruit production. Mites in particular are notorious for becoming resistant to acaricides. The average field life of an acaricide is listed at only 2-3 years (Hoyt 1976). Many of the organophosphates were acaricidal when first introduced, but lost that property very quickly. ODM is one of the few that is considered acaricidal.

Aphids have also developed resistance to a number of chemicals, but not with the rapidity of mites. However, the number of aphicides available for use on tree fruits, especially ones that are selective, is dwindling. The broad-spectrum materials, such as methomyl and the pyrethroids, are not favored because of their toxicity to beneficial insects.



Table 11. Alternatives to oxydemeton-methyl on non-bearing fruit crops

State	Target pest	Chemical	Application rate	No. applications	Appl. <sup>a</sup> method	Relative <sup>b</sup> efficacy
Washington	aphids	phosphamidon	0.75	1	G,A	G
		endosulfan	1.50	1	G	F
		methidathion <sup>c</sup>	2.00	1	G	F-G
		parathion <sup>c</sup>	1.00	1	G	F-G
		diazinon <sup>c</sup>	2.00	1	G	F-G
		dimethoate	1.25	1	G	F
West Virginia		dimethoate				
		phosphamidon				
		endosulfan				
		methomyl				
New Jersey		endosulfan	1.00	2	G	E
		parathion	0.50	8	G	E
		malathion	0.25	8	G	E
New York	mites	disulfoton	0.03	1	G	C
Washington		propargite	1.80	1	G	G-E
		fenbutatin-oxide	1.00	1	G	F-E
		formetanate	1.00	1	G	G
West Virginia		formetanate				
		dicofol				
		oxamyl				
		amitraz				

<sup>a</sup>G=Ground, A=Air.

<sup>b</sup>E=Excellent, G=Good, F=Fair.

<sup>c</sup>Used primarily at the delayed dormant period against overwintering eggs.

All of the aphicides recommended for apple aphid in Washington have some drawback. Phosphamidon is phytotoxic to 'Delicious', the primary apple cultivar. Its use on bearing fruit was withdrawn for many years because of this problem. Endosulfan appears to be losing effectiveness against apple aphid, and dimethoate is only moderately effective (Beers & Elsner 1989).

### Pest Management

As with most indirect pests, there is usually a greater potential for biological control. Economic injury levels tend to be higher when the salable product is not directly affected. In the case of nursery stock, the tree is in itself the salable product; in the case of non-bearing fruit trees, there is no salable product (by definition), but indirect pests can affect future crops. In the case of both mites and aphids, there is a significant potential for integrated control.

**Mites:** The success of integrated control programs varies widely between crop species and growing region. Mites tend to be a major concern on apples, but only an occasional problem on plum, prune, apricot, peach, nectarine, and cherry. The common mite predators fall into two classes: 1) predatory mites in the family Phytoseiidae, including *Amblyseius fallacis*, *Typhlodromus occidentalis* and *T. pyri*; 2) predatory coccinellids, including *Stethorus punctum* and *S. picipes*. There are many other insects that will prey on mites, but the list above includes those around which successful programs have been built.

The key to integrated mite control in tree fruits in general is the other (usually direct) pests that occur, and the chemical controls used against them. The use of chemicals toxic to mite predators (whether aimed at phytophagous mites or other pests) have resulted in population explosions of mites. The general observation is that mites are an induced pest, occurring only in low numbers under unsprayed conditions. However, control of direct pests is unnecessary in non-bearing orchards, thus mites are rarely a problem. Only chemicals used against other indirect pests need be scrutinized for toxicity to predators.

**Aphids:** Because they thrive on flush growth, aphids are more likely to be a problem in non-bearing orchards than mites. There is a complex of generalist predators for aphids, including lacewings, coccinellids, syrphid fly larvae, cecidomyiid larvae, predatory bugs, and earwigs. There are also several hymenopterous parasitoids that will attack aphids. However, these natural enemies tend to be very susceptible to orchard chemicals (more so than predatory mites, which have been selected for quite heavily). Overall, integrated control of aphids is less reliable than that for mites, and host plant conditions for their growth and reproduction on non-bearing trees is optimal.

### **Pesticide Application Methods**

There are two methods of applying pesticides: by ground, typically an airblast sprayer drawn by a tractor and equipped either with a power take-off from the tractor or with a separate engine; and by air, either fixed wing or helicopter. Aerial application is advantageous in that an entire farm in a matter of hour vs. several days, and this is a useful feature when timing of sprays is critical. Its main disadvantages are less thorough coverage, which does not provided sufficient control for some pests. However, aphids are quite amenable to aerial application, because the flush growth which supports them tends to be on the outside of the tree canopy. Per acre gallonage for airblast sprayers varies considerably among (and within) regions and target pest, but often one gallonage predominates. In Washington, growers typically spray dilute, which is from 100 to 600 gallons/acre depending on tree size, with 400 gallons considered standard for mature orchards. The 100 gallons/acre is more typical for dilute coverage of non-bearing trees. In Pennsylvania, 50 gallons concentrate spray/acre is considered standard.

The primary hazard during application is to the applicator. Most of the alternative chemicals listed specify that personal protective equipment must be worn. This can take two forms: an enclosure around the cab of tractor, or protective clothing. Enclosed cabs are little used in some states because of tight row spacings (hence potential for fruit damage) but are more common elsewhere. Helmets with a forced air supply through a filtering system are becoming more popular and help reduce the amount of applicator exposure. Because tractor-drawn airblast sprayers are slow (1 to 4 miles per hour) and very noisy, accidental exposure of workers in the orchard is less likely.

Aerial application gallonage varies also with the type of equipment used, but 20 gallons per acre is about maximum; 7 gallons/acre is more typical. The higher concentration of pesticide in the finished spray volume and the speed with which acreage is covered make this type of application more hazardous to orchard workers. In order to be applied by air, the label must specify that this application method is allowed.





## **Oxydemeton-methyl Use on Strawberries**

Elizabeth H. Beers  
Washington State University

Oxydemeton-methyl is labelled for use on strawberries in Washington and Oregon only under a 24(c) Special Local Needs label (WA 85003 and OR 79-0067). Between them, these two states have ca. 10,330 acres, or 25.6% of the U.S acreage of spring strawberries (all winter strawberries are in Florida) (Anonymous, 1986). These states are competing with strawberries grown in California, which has 15,600 acres. Most of the berries in Washington and Oregon are used for processing.

The 24(c) label for ODM is for strawberry aphid, Chaetosiphon fragaefolii (Cockerell). Although it used to have a national label that extended throughout the growing season, it currently can only be used pre-bloom (1 application maximum) and post harvest (2 applications maximum). This pest is important primarily because it vectors several strawberry viruses: mottle, mild yellow-edge, and crinkle virus. Before adequate aphid control measures were taken, viruses were a severe problem. Differences in horticultural practices make aphid control imperative in Washington and Oregon. In these states, fields are left in for 2-3 years, and viruses have time to become established. In California, strawberries are essentially grown as annuals, that is, fields are plowed under and replanted every year. This system does not allow viruses to build up to any degree.

### **Oxydemeton-methyl Usage**

Workers in Oregon estimate that 80% of the acreage receives 2 applications of ODM per season, while those in Washington estimate that 50% of the acreage receives 3 applications of ODM. The rate for both states is 0.5 lb AI/acre (2 pints) (Table 12).

### **Alternative Chemicals**

Diazinon, azinphosmethyl, and chlorpyrifos are alternatives, but ODM is considered to provide superior control. In addition, these materials are applied directly to the fruit. In most cases, a typical ODM program (1 prebloom and 1 post-harvest application) provides season-long control without the use of in-season insecticides. If ODM were removed from the market, growers would have to make 1-2 more insecticide application than they currently do, and these would be made when the fruit is present.

### **Summary**

If ODM label for strawberries were removed, there would be no immediate loss or gain. However, if aphids became resistant to the alternative OP insecticides, or if one or more of these materials were also withdrawn, growers in Washington and Oregon would suffer declining yields due to viruses. Acreage in Washington is decreasing, in part because of competition from California. Loss of ODM could contribute to this process. As of this writing, the registrant (Mobay) does not intend to continue support for a registration on strawberries.



Table 12. Alternative chemicals to oxydemeton-methyl for strawberry aphid

State	Chemical	Treatment rate (lbs ai/A)	No. treatments	Cost/ <sup>a</sup> treatment (\$)	Application <sup>b</sup> method	Relative <sup>c</sup> efficacy
Washington	Diazinon	0.50	2	2.50	G	F
	Azinphosmethyl	0.50	3	3.00	G	G
Oregon	Chlorpyrifos	0.50	2	14.00	G	C
	Azinphosmethyl	0.50	2	17.50	G	C
	Diazinon	0.50	2	14.00	G	C

<sup>a</sup>Cost of application not included in treatment costs for Washington.

<sup>b</sup>G=Ground.

<sup>c</sup>G=Good, F=Fair, C=Comparable.

## Oxydemeton-methyl Use on Filberts

Helmut Riedl  
Mid-Columbia Experiment Station

Oxydemeton-methyl (ODM) has special local need labels for aphid control on filberts in Oregon (EPN SLN No. OR-800079) and Washington (EPN SLN No. WA-800077). The label specifies a rate of 2 pints per acre of the 2 EC formulation, applied once per season with a 105 PHI (pre-harvest interval).

Commercial filbert production in the United States is restricted to the Pacific Northwest partly because filbert trees cannot tolerate extremes in dry summer heat or winter cold. Orchards are located between the western foothills of the Cascade Mountains and the eastern slope of the Coast Range from Vancouver, Washington to Eugene, Oregon. More than 95 percent of this acreage, approximately 25,000 acres, is in the Willamette Valley. Washington is the only other state that produces commercial quantities of filberts. Production is limited to less than 1,000 acres, mostly in the Vancouver area. Filbert production contributes 16 million dollars annually (average 3-year farm gate value 1985-1987) to the agricultural economy of the Pacific Northwest (Table 13).

Table 13. Filbert production and oxydemeton-methyl usage on filberts

State	Area planted	Yield <sup>a</sup>	Total <sup>a</sup> value	Area <sup>b</sup> treated	Amt ODM used
	(A)	(lbs/A)	(million \$)	(A)	(lbs ai)
Oregon	26,000	1556	15.9	110	55
Washington	400	1340	0.3	0	0

<sup>a</sup>Average for 3-year period 1985 to 1987 (Source: Oregon Agriculture and Fisheries Statistics, 1987-1988).

<sup>b</sup>Source: Oregon Pesticide Use Estimates for 1987, Oregon State Univ. Ext. Serv. Special Rep. 843 (1989).

### Pest Management

The only target of oxydemeton-methyl use on filberts is the filbert aphid, Myzocollis coryli (Goeze). It is among the major pests of filbert and usually requires annual treatments. Other pests of filbert include the filbert worm, Melissopus latiferreanus (Walsingham), an internal nut feeder; two leafrollers, the filbert leafroller, Archips rosanus (L.) and the obliquebanded leafroller, Choristoneura rosaceana (Harris), both of which do damage to foliage and nuts (external); and two species of eriophyid mites which can damage female flowers, catkins, and leaf buds.

Of relatively minor importance are scale insects such as European fruit lecanium, Lecanium corni Bouchi, the Syneta beetle, Syneta albida Lec. and the eyespotted bud moth, Spilonota ocellana. The overall yield reduction caused by insect and mite pests in unsprayed orchards has been estimated to be about 20%. It is not unusual to find 15 to 20% of the nuts damaged by the filbert worm. Another 5 to 10% loss can be caused by the filbert leafroller and the filbert aphid (AliNiazee, 1980).



The filbert aphid is of European origin and was first detected in 1903. It is now distributed throughout the filbert-producing areas of Oregon and Washington. The filbert aphid overwinters in the egg stage. Nymphs are first seen on the developing buds in early spring. Later they feed on the underside of leaves producing honeydew. Infestations reduce nut size and percent fill. Filbert trees can tolerate moderate populations (5 to 10% of terminals infested in early season, 20% in July and August), but heavy populations should be controlled.

A number of predators and parasitoids feed on filbert aphids such as syrphid larvae, ladybird beetles, and predaceous bugs. A small braconid parasitoid, *Trioxys pallidus*, was recently introduced from Europe and released in the filbert-growing area. This species is apparently not established but it is too early to assess its impact. Dormant sprays to control aphid eggs have no harmful effects on predators. However, foliar sprays especially with broad-spectrum materials, will interfere with natural enemy activity.

Monitoring and scouting methods as well as guide lines for making control decisions have been developed for the filbert pest complex (Caulkin and Fisher, in prep.) About 10% of the filbert orchards are regularly inspected by independent pest management consultants who make control recommendations according to population levels. Another 50% of the acreage is being serviced by fieldmen who work for agricultural chemical distributors. In the remaining orchards growers either follow a standard spray program (Capizzi, 1988) or practice various degrees of pest management based on their own observations and monitoring of pest activity. The action thresholds for controlling filbert aphid are 10 aphids per leaf in April, 30 in May and 40 in June. Aphid control after June is generally not necessary due to the natural decline of populations caused by high temperature.

### **Application of Pesticides**

Low volume spraying is a widely accepted practice on filberts. Sprays are applied by airblast equipment from the ground. The spray volume applied per acre ranges from 25 to 100 gallons (avg 50 to 60). Spray coverage can be difficult in old orchards due to dense canopies and large tree size. Wearing of protective gear by workers involved in the spraying operation is standard practice.

### **Oxydemeton-methyl Usage and Alternative Chemicals**

About half of the total filbert acreage is treated annually for control of filbert aphid. Estimates of current oxydemeton-methyl use on filberts range from 2 to 10% of acreage treated once per year (Table 13). Earlier ODM use on filberts was reportedly much higher. Reasons for the lower ODM use today are: (a) decline in effectiveness, (b) availability of more effective compounds, (c) toxicity to humans, (d) availability of alternatives which are not restricted use pesticides, (e) the narrow spectrum of activity and the very long pre-harvest interval (105 days). Resistance is suspected as the reason for the gradual decline in effectiveness of ODM for filbert aphid control. However, this assessment is only based on field observations and is not confirmed by laboratory tests. Perhaps the biggest factor responsible for the decrease in ODM use on filberts is the availability of better materials. Several alternative chemicals are registered for filbert aphid control. Those chemicals reported by survey respondents as ODM alternatives are listed in Table 14.

Considering its low per acre cost, ODM would be an attractive choice for aphid control, e.g., \$6.50 for ODM versus \$8.40 for diazinon and \$16.70 for chlorpyrifos. However, ODM does fall short in terms of efficacy and spectrum of activity when compared to alternative chemicals. Of the alternatives listed in Table 14 chlorpyrifos is the most effective aphid material. Diazinon, phosalone and endosulfan are better or similar to ODM in effectiveness. Chlorpyrifos is more widely used today for filbert aphid control than other compounds. Another reason for its popularity is its effectiveness against a range of filbert pests. Chlorpyrifos, like diazinon and phosalone, has a broader activity spectrum. Broader activity is desirable in

situations where the timing for an aphid and leafroller treatment coincides. About 15 to 20% of the filbert acreage is treated annually to control leafrollers. In orchards where aphids and leafrollers need to be controlled at the same time ODM would be a more expensive choice since a leafroller material would also have to be added. Chlorpyrifos, diazinon or phosalone as well as endosulfan would control both aphids and leafrollers. A further limitation of ODM use on filberts is the long pre-harvest interval of 105 days. Nuts are harvested in early to mid-September. Because of the long pre-harvest interval use of ODM is limited to a short period in April and early May. Alternative chemicals have much shorter PHI's ranging from 0 days for diazinon to 30 days for phosalone (Table 2) and, therefore, they can be used throughout the 3-month period from April through June when aphids are generally controlled. The safety of ODM to bees due to its systemic activity is a positive aspect of this material. However, filberts are wind-pollinated and bee toxicity is not an important concern on this nut crop. Alternative chemicals are likely to be more disruptive than ODM to predators and parasitoids of filbert aphid and other filbert pests due to higher contact toxicity and the use later in the season. No detrimental effects on nut quality or yield have been observed with any of the chemicals recommended for aphid control on filbert.

Table 14. Alternative chemicals to oxydemeton-methyl for aphid control on filberts in Oregon and Washington

Chemical	Application rate (lbs ai/A)	PHI days	Preharvest interval (days)	Target pest	Treatment cost*	
					-----(\$)------ /lb ai	/acre
chlorpyrifos	1.5-2	14		filbert aphid, leafroller, filbert worm	11.10	16.70
diazinon	1-2		0	same	8.40	8.40
phosalone	1.5-2		30	same	11.00	16.50
endosulfan	1.5-2	0		filbert aphid, leafroller	10.80	16.20
oxydem.-methyl	0.5		105	filbert aphid	13.00	6.50*

\*Local prices.

## Summary

Two of the presently recommended oxydemeton-methyl alternatives for filbert aphid control may be permanently lost to the industry. CIBA-GEIGY Agriculture Division announced in a letter dated May 19, 1989, its intention to discontinue all uses of diazinon on filberts as a result of EPA's re-registration process. The company stated that sales volume on filberts does not justify the expense of data development for re-registration. Additionally, Phone-Poulenc has withdrawn phosalone from all of its markets while tests on the materials safety to workers are being conducted. This reduces the list of registered ODM alternatives to two, chlorpyrifos and endosulfan. Although ODM has not seen much use for aphid control on filberts in recent years the shortage created by the apparent loss of diazinon and phosalone may; again increase the need for an aphicide such as ODM. In light of these developments, the additional loss of ODM would be critical and would further limit the ability of filbert growers to manage one of their most serious pest problems.





## Oxydemeton-methyl Use on Walnuts

Helmut Riedl  
Mid-Columbia Experiment Station

Oxydemeton-methyl has a federal label for aphid and mite control on walnuts. The label specifies a dosage of 1.5 pints in 100 gallons of water applied as full-coverage spray once per season. The pre-harvest interval (PHI) is 30 days.

More than 90% of the U.S. walnuts, also known as Persian or English walnuts, *Juglans regia* L., are grown in California. Small acreages of walnuts can be found in Oregon and Washington west of the Cascade mountains. However, production in these two states is insignificant and is not reported by the respective Agricultural Statistics Services. Total walnut acreage in California has increased from about 140,000 acres in 1953 to over 180,000 acres today. Walnut production has grown even more dramatically from about 60,000 in-shell tons in the mid-1950's to 245,000 tons in 1987. This increase in production is related in part to new heavy-bearing varieties and denser plantings. The walnut industry contributes 196.8 million dollars annually (average 3-year farm gate value 1985 to 1987) to the agricultural economy of California (Table 15).

Table 15. Walnut production and oxydemeton-methyl usage on walnuts in California

No. acres harvested	Yield <sup>a</sup>  (tons)	Total <sup>a</sup> value  (million \$)	oxydemeton-methyl usage <sup>b</sup>	
			No. acres	Quantity  (lbs ai)
178,300	1.20	196,818	1,096	928*

<sup>a</sup>Average for 3-year period 1985 to 1987 (Source: California Agriculture Statistical Review, California Dept. of Food and Agriculture).

<sup>b</sup>Source: Annual Pesticide Use Report for 1986, Calif. Dept. Food and Agric.

### Pest Management

Although labeled for mite as well as aphid control on walnuts, oxydemeton-methyl has not seen much use as a miticide on this crop. The two aphid species on walnuts which may have to be controlled are the walnut aphid, *Chromaphis juglandicola* Kaltenbach and the dusky-veined aphid, *Callaphis juglandis* (Goeze). The walnut aphid was once among the major pests of walnuts but is now mostly controlled by an introduced parasitic wasp. Since the biological control of walnut aphid, the dusky-veined aphid has become a pest problem in some orchards. Other pests of walnuts include the codling moth *Cydia pomonella* L., and the navel orangeworm, *Amyelois transitella*, both internal nut feeders; the walnut husk fly *Rhagoletis completa* Cresson, whose maggots destroy the husk; scale insects such as European fruit lecanium, *Lecanium corni*; walnut scale, *Quadraspidiotus juglansregiae*, and San Jose scale, *Quadraspidiotus perniciosus*, all of which infest the bark; and several foliage feeders including spider mites and lepidopterous pests.

Both aphid species on walnuts have a similar life cycle. They overwinter in the egg stage on the twigs. As leafbuds open, eggs begin to hatch. Aphids pass through many generations. They are most damaging in spring and early summer when nuts develop rapidly and are very susceptible to stress. Aphid feeding, depending on intensity, can reduce tree vigor, nut size,



yield and quality. Honeydew discharged by feeding aphids will settle on the husk and provide substrate for sooty mold growth. Heavily infested leaves may also drop and increase the chance of sunburn. Walnut aphids of 15 or more per leaflet in early season reduce yield and quality. Summer infestations lower nut quality. Action thresholds have been established for the dusky-veined aphid. If 10 to 15% of the leaflets are infested for 3 to 4 weeks before shell hardening nut size is decreased.

The walnut aphid was a serious problem before the parasitic wasp Trioxys pallidus was introduced (Van den Bosch et al. 1970). The key to walnut aphid management is to preserve this biological control agent by choosing insecticides and application schedules necessary for the control of other walnut pests which are not harmful to Trioxys. Predatory insects such as ladybird beetles, lacewings and predaceous bugs are also important for controlling aphids. Dusky-veined aphid is not as well controlled by natural enemies as walnut aphid and, therefore, requires chemical control in some years. Unless biological control of walnut aphid is disrupted by chemical sprays, control is necessary in less than 5% of the walnut orchards.

Integrated pest management is well-established on walnuts. Methods for monitoring pest populations and control action guidelines are available and are well documented (Anonymous 1982). About 20% of the walnut acreage is under pest management by private, independent consultants. Another 30 to 40% of the walnut acreage is regularly inspected by pest control advisors (PCA's) who are employed by distributors of agricultural chemicals. On the remaining acreage growers practice various levels of pest management based on their own observations and following the University of California's recommendations (Hendricks et al. 1987).

### **Application of Pesticides**

Most Juglans regia varieties are large spreading trees which can grow to 50 ft tall when mature. Size-controlling rootstocks are not available for walnuts. The older light-bearing varieties grew very large and were difficult to manage. Many of today's varieties are smaller trees and can be planted closer. Spray coverage on large walnut trees has always been a problem, even with specialized equipment. In the new higher-density plantings spray operations are more efficient and easier to carry out because of smaller tree size. Cumbersome spray towers with oscillating spray guns were used in the 1940's to achieve adequate coverage (Riedl et al. 1979). This equipment has now been replaced by air-carrier sprayers with special chutes to direct the spray into the upper canopy. However, spray coverage with this new equipment, especially in the tops of trees, is often not adequate. Aerial application by helicopter or fixed-wing aircraft has been employed only to some extent on walnuts in addition to ground treatments to improve coverage. Spray volumes applied per acre range from 100 to 250 gallons.

### **Oxydemeton-methyl Usage and Alternative Chemicals**

Current use of oxydemeton-methyl for aphid control on walnuts is very low. Less than 1% of the walnut acreage was treated with ODM in 1987 (Table 15). A total of 928 lbs ai were applied to this acreage (0.85 lbs ai per acre) that year.

Although federally labeled, ODM is presently not listed as an option for aphid control on walnuts in the University of California Walnut Pest Management Guidelines (Hendricks et al. 1987). There are several reasons why ODM use is so low today. First, the successful introduction of the walnut aphid parasite, Trioxys pallidus, has eliminated the need for chemical control of the walnut aphid in most years. Although the dusky-veined aphid can be a problem at times, other materials are available which are used in place of ODM. Concerns about direct toxicity to the applicator and ODM's classification as a restricted-use pesticide are additional reasons for its low use today.

Several alternative chemicals are registered for aphid control on walnuts. Chemicals reported by survey respondents are listed in Table 16. Phosalone is the least disruptive to

the walnut aphid parasitoid. Diazinon, phosalone, and phosphamidon usage may result in a spider mite build-up. The latter material may also cause a resurgence in aphid populations and induce outbreaks of scale insects. The narrow spectrum of ODM is not a draw-back since sprays specifically applied against aphids do not coincide with the timing of worm sprays. ODM, due to its systemic activity, is inherently more selective to natural enemies of the two aphids on walnuts. ODM's selectivity to bees is not a major plus since walnuts are wind-pollinated. The listed chemical alternatives appear to cause no particular plant safety problems when used according to the label. No nut yield or quality reductions have been observed with any of the alternative chemicals.

Table 16. Pesticide alternatives to oxydemeton-methyl for aphid control on walnuts in California

Chemical	Application rate	Preharvest interval	Target pest	Treatment cost (\$)*	
	(lb/A)	(PHI days)		/lb ai	/acre
diazinon	1	HS <sup>b</sup>	scale insects, aphids	8.40	8.40
phosalone	0.75-1.5	HS	codling moth, aphids	11.00	8.25
endosulfan	1.5-2	HS	aphids	10.80	16.20
phosphamidon	1	7	aphids, walnut husk fly		
oxydem.-methyl	0.375	30	aphids	13.00	4.88

\*California prices.

<sup>b</sup>Not applied after husk split (HS).

## Summary

Oxydemeton-methyl has not been an important chemical for aphid control on walnuts in recent years as the low use of this compound indicates. However, two widely used aphid materials may not be available to walnut growers in the future. CIBA-GEIGY Agricultural Division announced in a recent letter dated May 19, 1989, its intention to discontinue all uses of diazinon on walnuts as a result of EPA's re-registration process. The reason given was that sale volume on walnuts does not justify the expense of data development for re-registration. Additionally, Rphone-Poulenc has withdrawn phosalone from all of its markets while tests on the materials safety to workers are being conducted. These actions reduce the number of available ODM alternatives to endosulfan and phosphamidon. The latter does not fit well into IPM programs due to its disruptiveness. Because of the threatened withdrawal of diazinon and cancellation of phosalone the loss of another aphid material could seriously affect the ability of growers to manage aphid populations successfully on walnuts. Retaining ODM as an option for aphid control on walnuts should, therefore, be considered under the present circumstances.





## OXYDEMETON-METHYL USE ON VEGETABLES

Richard Straub, Cornell University  
Charles J. Eckerode, Cornell University  
Richard Ashley, University of Connecticut

Oxydemeton-methyl (ODM) is used for the management of sucking insects and mites that attack vegetable crops. ODM is particularly suitable to many management programs because of its efficacy against specific target pest, its short residual and its safety on pollinating insects. It has the unique properties of being a systemic (ie., absorbed into the foliage, and travels within the sap to protect the plant from sucking pests), and being a miticide as well as an insecticide.

Oxydemeton-methyl is registered for use on more than 19 separate vegetable crops (lima beans, broccoli, Brussels sprouts, cauliflower, cabbage, cucumbers, eggplant, head lettuce, onion, pea, pepper, potato, pumpkin, squash, turnip, muskmelon, other melons, and watermelon. Data were gathered from surveys of extension and research personnel from every state in the U.S. Those that reported significant ODM major usage on vegetable crops are:

California	K. Kido; W. E. Chaney
Florida	N. Nesheim
Indiana	A. C. York
Kansas	D. O. Cress
Maryland	J. J. Lindudska
Michigan	E. J. Grafius
New Jersey	E. J. Grafius
New York	A. T. Shelton; E. Rutkowski
Oklahoma	R. Cartwright
Texas	A. Sparks, Jr.
Washington	D. F. Mayer

To confine this assessment to a manageable size and scope, specific vegetable crops were selected for evaluation on the basis of local pounds used. This procedure, though necessary, may ignore the beneficial usage of ODM on some of the minor crops in specific management situations - this is unfortunate because the total parameters of ODM benefits may be underestimated. It is inherent in this treatment of benefits, that the total volume of material used on a crop or the percentage of the crop treated do not realistically indicate the relative importance of the material to vegetable producers. Some of the minor crops, such as Brussels sprouts, accounted for little ODM usage, but needed to be included because ODM fills a specific niche in management programs. We therefore lumped selected minor crops into crop groups, ie., 'cucurbits' (squash, pumpkin, cucumber, and melons), and 'crucifers' (cabbage, broccoli, Brussels sprouts and cauliflower). These crop groups best illustrate the importance of ODM to vegetable production. Table 17 indicates the value of each crop. Aphids (many species) are one of the most important insect pests controlled by ODM. They are widely distributed in all areas of the U.S., affect every vegetable crop and are economically important in most locations. They reproduce parthenogenetically, and may therefore multiply rapidly under favorable conditions, producing overlapping generations. They may injure plants in four ways: 1) by sucking plant juices they reduce plant vigor and subsequent yields; 2) physically contaminate the fresh or processed product by their presence; 3) Contaminate plants by the production of honey dew, upon which 'sooty-mold' fungus develops; and 4) by vectoring plant diseases. The presence of one or more of these factors necessitates aphid control in most instances. Natural factors (eg., heavy rainfall, lady beetle larvae, syrphid larvae, several hymenopterous parasites, entomopathogenic diseases, and insectivorous birds) may keep aphid populations in check in specific situations. Due to the 'cosmetic' standards for fresh produce however, natural factors generally have to be supplemented by aphicide treatments.



Thrips (primarily onion thrips, Thrips tabaci and Western flower thrips, Franklinella occidentalis) are widely distributed in the U.S. and may damage most all vegetable crops. They may reproduce parthenogenetically and can multiply rapidly under favorable conditions, producing overlapping generations. They are small soft-bodied insects that injure plants and fruits by scoring the tissue with rasping mouthparts, and sucking up exuding plant juices. Yield reductions are caused by the reduction of photosynthate and possibly by increased waterloss through stimulated respiration. In cabbage, thrips often are present between leaves of the harvested head, and thereby contaminate the product. Populations may be reduced by weather factors such as rainfall, but few natural enemies are known to be effective.

Mites (primarily two-spot, Tetranychus urticae) are found throughout the U.S. and infest most vegetable crops; most notably cucurbits, tomato, eggplant, celery, beans and sweet corn. Spider mites may reproduce both sexually and asexually, and can therefore multiply rapidly under favorable conditions. They have well developed dispersal mechanisms, enabling them to spread over large areas and to colonize widely separated host plants. Heavily infested leaves may cup inward, or the entire leaf may turn yellow and die. Yield effects may be manifest through physiological shock to the plant. Few insecticides are effective as miticides, and spider mites are able to rapidly develop resistance to a variety of chemical groups. Predatory mites such as Phytoseiulus persimilis and Amblyseius fallacis are effective biological control agents, but are notoriously susceptible to many insecticides, particularly the pyrethroids (Smith and Newsom, 1970).

Oxydemeton-methyl is used on a wide variety of vegetable crops. Use patterns, as determined from survey respondents, indicate that is most often used selectively in specific problem situations at relatively low dosages (0.25 - 0.50 lb AI/acre) and with minimal numbers of applications (1 -3), rather than as a broad-spectrum treatment. It does not appear to be a major tool on a consistent basis in many areas, but it's major utility is in situations that require an insecticide having one or more of the following attributes: 1) systemic activity; 2) effective against sucking insects; 3) effective against mites 4) safe on pollinators; and 5) low (no. of days) harvest interval. Because of its rather unique qualities, ODM fills niches that cannot be filled by some of the new pesticide chemistries, eg., pyrethroids. There is scant current research data on the relative efficacy of ODM and alternative chemicals. The Journal of Economic Entomology was searched for the 25 yr. period 1963-88, and additionally, Insecticide and Aracracide Tests was searched for the period 1966 - 88. This represents a comprehensive survey of ODM research on vegetable and is presented in Table 18.

### Limitations of Analysis

One must be mindful that assessment based on mail surveys have limitations for many reasons. Because of failure to reply, many state specialists had to be contacted by phone. In such cases, the common reply was "...not recommended in this state", or "...insignificant amounts used". While this may be valid, it could ignore the many specialty uses of relatively small amounts of ODM, and consequently doesn't account for unique infestation situations in which ODM may be valuable to individual producers. Also, the limiting of assessment to only crucifer and cucurbit crops, while they may be most important to ODM usage, fails to address other crops (potato, beans, eggplant, lettuce, sweet corn, etc.) on which ODM is a sometimes invaluable tool for pest management.

### Summary and Conclusions

Plant protection against vegetable crop pests is as variable as is the types of vegetable grown. It is characterized by sporadic infestations from a variety of insects that may only occur at economic levels once in a decade. These populations fluctuate according to weather, the mosaic of host plants available, impact from natural enemies that also fluctuate, and other factors. Many effective insecticides such as ODM are used infrequently and their value to vegetable producers cannot be documented solely on the basis of total pounds used.

The extensive use of ODM on cucurbit crops as an aphicide during pollination is a key factor in the assessment of benefits. Many alternative insecticides and some of the newer pesticide chemistries cannot be used in such instances because of toxicity to bees and other pollinators. So too, ODM has specific prescription uses in broccoli and Brussels sprouts production. An objective of the evaluation process, should be to preserve 'specific-use' insecticides where possible. The concept of integrated pest management is well served by having such tools available.

Regarding exposure, "...the applications [of ODM] involving fixed wing airplanes, helicopters, and row crop tractors with spray booms directly above the row crop, resulted in the lowest levels of worker exposure. The airplane pilot would have the least exposure with the helicopter pilot receiving somewhat more exposure. The exposure to the flagger can be somewhat variable. The row crop tractor driver's exposure would be low. The exposure of the mixer-loader for the aircraft could result in the highest exposure and the mixing and loading of MSR [ODM] for the row crop tractor would result in somewhat less exposure. However, the mixing, loading and the driving (application) of the row crop tractor is usually a one-person job. Closed system pumping of liquid formulation[s] significantly reduces mixer-loader exposures" (Maddy, 1986). ODM is not employed as a broad-spectrum treatment, but rather is used at low rates with minimal numbers of applications. These factors reduce total applicator and worker exposure, and should reflect upon the potential for reproductive effects.





## Oxydemeton-methyl Use on Cruciferous Crops

Oxydemeton-methyl (ODM) has federal registrations for control of aphids on cruciferous crops (broccoli, brussels sprouts, cabbage, cauliflower) in every state. In addition, it is registered on turnip for the control of aphids and mites. Since thrips as contaminants, are a serious problem in at least one state (NY), ODM is recommended under Sec. 2EE of FIFRA (Annon., 1988). While many states do not recommend or use ODM on cruciferous crops, many do rely on it in specific situations. The major users are listed in Table 3. ODM 2SC is recommended at 1.5 to 3 pints (0.375 to 0.75 lb AI/acre); not more than 3 applications per season; with varying harvest intervals of 7 to 10 days. Respondent states recommend 1 to 3 applications at 0.5 lb AI/acre.

The primary target pest is the cabbage aphid, Brevicoryne brassicae, and in lesser instances, the turnip aphid, Hyadaphis pseudobrassicae. These aphids may attack the crop in seedbeds and at any subsequent growth stage until harvest. Leaves may be covered with dense clusters, which suck sap from the leaf. Affected leaves crinkle, form cups, and in severe infestations, wilt and die. The plants if not killed, are dwarfed, grow slowly, and form under-sized heads not suitable for market. In most production areas, uncontrolled populations can cause greatly reduced yields.

In most areas of intensified production, organized IPM programs have been implemented to at least some extent. These programs entail regular field scouting, with recommendations for treatment based on thresholds. In most cases, IPM programs concentrate on the primary pests (cabbage maggot, cabbage looper and diamondback moth), but scouting for aphids, thrips and mites are regular inclusions of programs. The proportion of cruciferous crops produced with the aid of IPM programs is not known, but could be as high as 50%. Some cabbage varieties have resistance to thrips (Anon., 1988). Significant levels of host resistance to aphids is not known in cruciferous crops. Aphids have a number of natural enemies (eg., lady beetle larvae, syrphid larvae and entomopathogenic fungi), but in most instances they alone are rarely efficient enough to replace insecticides for control. ODM has been reported to be relatively safe on beneficials (Simcoe, 1989), and there is no evidence that ODM is more toxic to beneficials than are the alternatives. Insecticides employed on a regular basis to control other insects (eg., cabbage looper and diamondback moth) are likely to be more harmful to beneficials than ODM.

Five states reported ODM usage on cruciferous crops (Table 19), representing approximately 212,944 acres of total production. Approximately 90% of the acreage was treated with ODM, directed primarily against aphids. Treatment for aphids is annually necessary in all areas. ODM is applied on 'as-needed' intervals, with 1 to 3 applications; 2 applications appears normal for aphids, with the maximum of 3 applications for thrips. Florida reported only 1 application on 284 acres for aphid control. Texas reported multiple applications on 50% of 25,560 acres. Most states reported the treatment dosage at 0.5 Lb AI/acre; the range 0.25 to 0.5 lb AI/acre. Treatments commence on 'as needed' basis, or when established thresholds have been reached. In the warmer climes, such as California and Texas, treatments are necessary in seedbeds, where seedlings are grown for transplanting. Heavy infestations at this stage can reduce plant vigor and lead to poor transplant success. The primary method of application is by ground (boom and air blast) equipment, with complete coverage of the plant recommended (Anon., 1988). California reported both ground and aerial applications, with no relative percentage given. Ground treatments are applied at approximately 75 gallons per acre ranging between 50 and 150 gpa. Aerial treatments are applied at 2 to 10 gpa (Anonymous, 1979).

In the states having large acreages, production is concentrated, and crucifer crops may not be in close proximity to other crops. In these usual cases, ODM applications are not in conflict with other crops or environmental situations. In areas of mixed vegetables or other crop production, drift onto nontarget areas is more likely. The use of ground equipment however, allows producers some control over this situation. For aerial applications, adherence



to state mandated buffer zones, where present, would greatly limit drift contamination. There is no evidence that off-target drift would be any greater for ODM than for the alternative insecticide treatments.

Continuous cropping of crucifers is not a common practice. Rotation is encouraged by potential soil-borne disease problems (clubroot, blackleg and black rot) that arise from continuous crucifer production. Rotation out of crucifers decreases the incidence of overwintering aphids and thrips in the current seasons crop. Such rotations, and the relatively modest usage of ODM in most cases, can be instrumental in reducing the development of resistance to this chemical. ODM usage on crucifers is mostly confined to selective applications for specific pest outbreaks rather than as a broad-spectrum material used on a preventative basis. Few, if any instances of resistance have been reported.

### **Alternative Chemicals**

The chemical alternatives to ODM is indicated by the responding states, are listed in Table 20. Eight alternatives for aphids and two for thrips are listed. Acephate is an excellent aphicide, but is registered only on cauliflower and Brussels sprouts. Methomyl is not label approved for aphids on crucifers, and must be applied under Sec. 2EE of FIFRA - not all states are able to use 2EE registrations. From research results the remaining alternatives are rated less effective than ODM (Table 2). No survey respondents reported the alternatives superior to ODM for aphid or thrips control. Texas reports no suitable alternatives for aphids on 25,560 acres of cabbage, cauliflower and broccoli grown in the Rio Grande Valley. California reported that 158,815 acres of broccoli, cabbage, and cauliflower are treated with ODM, and that it is generally better than the alternatives dimethoate, methamidophos, endosulfan, diazinon and mevinphos. On 3,155 acres of Brussels sprouts grown in Monterey and Santa Cruz counties, only ODM is effective in controlling aphids in the sprout itself. In these two counties, 96% of the approximately 33,000 acres of cruciferous crops are treated with ODM. New York with 17,800 acres of crucifers, reported no control advantage in the use of ODM for thrips control, but the three recommended alternatives (parathion, dimethoate, and mevinphos) are currently undergoing special review by the EPA.

Generally, the harvest intervals for the alternatives are not as favorable as the 7 day interval for ODM (Table 20). Assuming that all treatments require the same number of applications at the same rate, programs using ODM are more economical than those using methamidophos and methomyl; but more expensive than programs using mevinphos, endosulfan or diazinon (Table 21). Because of the variability in reported costs, and price variability among distributors, it is difficult to make cost comparisons and subsequent generalizations.

Two alternatives to ODM (dimethoate and mevinphos) are currently under special review by the EPA, and consequently their availability to producers cannot be assured. It is recommended that the re-registration status of alternate chemicals should be a major consideration in the benefits assessment process.

Only acephate, dimethoate and diazinon are less toxic to the applicator or workers. No more people are exposed to ODM than to any other alternative. In crucifer production, particularly for broccoli and cauliflower, hand labor may be used extensively. Although hoeing may be necessary in specific situations, weeds are controlled primarily by machine cultivation and herbicides. Worker exposure to ODM would be reduced by the 7 day harvest restriction. There is a 48 hr re-entry period for ODM - the probability of reproductive effects on workers could perhaps be lessened by adjustments of the re-entry period.

The regulatory removal of ODM would probably not greatly affect the nationwide production and supply of crucifers in any given year; however, in specific instances for specific crops, the unavailability of ODM would have a great impact upon production because viable alternatives are not available, or suitable for various reasons. For example, "...Metasystox-R is the only

registered pesticide to effectively control cabbage aphid in a Brussels sprouts and other cole crops....the loss of Metasystox-R to the cole crops in the Central Coast [CA] will significantly increase the cost of pest control, increase the volume of pesticides used while a lesser degree of control is achieved, and a multi-million dollar industry will be seriously threatened" (Marcroft, 1986). Nationally, the end result could be more expensive crucifers to the consumer, or a decreased supply that could result in greater importation of products from foreign sources; products perhaps treated with chemicals illegal for use in the US.





## Oxydemeton-methyl Use on Cucurbits

Oxydemeton-methyl (ODM) has federal registration for aphid and mite control on cucurbits cantaloupe, cucumber, mixed melons, pumpkin, squash and watermelon) in every state. While many states do not recommend or use ODM on cucurbits, many do rely on it in specific situations. The major users are listed in Table 6. ODM 2SC is recommended at 1.5 to 2 pints (0.375 to 0.5 lb AI/acre); once per season (pumpkin, watermelon, and squash), at not more than twice per season (cucumber), and not more than 3 times per season (cantaloupe and other melons). It has varying harvest intervals from 0 to 14 days. Respondent states recommend 1 to 2 applications per season (average rate 0.5 lb AI/acre), depending upon crop and situation.

The primary pest is the melon aphid, *Aphis gossypii*. This pest colonizes on leaf undersides, sucking plant sap, and can reduce plant vigor and both the size and quality of the fruit. This aphid has been considered by some, as the most destructive aphid in the USA. In many regions, it vectors cucumber mosaic virus, which can be devastating to yields. There are many strains of this virus, and its incidence cannot be greatly reduced by insecticide applications. Spider mites (primarily *Tetranychus urticae*) can be serious pests of cucurbits, particularly under hot, dry conditions. When infestations are high they cause severe physiological stress to cucurbits. Few insecticides are effective against this pest and it has shown a propensity to develop resistance to a variety of chemical groups.

For cucurbits in general, few IPM programs have been implemented. Cucurbits are susceptible to a number of diseases, and disease monitoring is probably the major objective of the programs that are active. There is little, if any, host resistance to aphids and mites in cucurbits. Aphids have a number of natural enemies (lady beetle larvae, syrphid larvae, entomopathogenic fungi), but in most instances they are rarely efficient enough to replace insecticides for control. Spider mites however, have two efficient natural enemies - the predaceous mites, *Phytoseiulus persimilis* and *Amblyseius fallacis*. In crop situations where predaceous mite populations are encouraged (eg., strawberry, tomato and apple), they have been effective. However, these natural control agents are notoriously susceptible to many insecticides, particularly the pyrethroids (Brown and Shanks, 1976). The effectiveness of predaceous mites to control spider mites on cucurbits is not known. There is no evidence that ODM is more toxic to beneficials than are the alternatives. ODM is however, relatively safe on honey bees and wild pollinators when compared to other insecticides (Cohick, 1988). ODM is important to cucurbit producers because of its safety on honey bees, when treatments are necessary at bloom (Cartwright, 1988).

Ten states reported ODM usage on cucurbit crops (Table 22), representing approximately 307,629 acres of total production. The major states are California, Texas, Florida, Oklahoma, Maryland and Indiana. Approximately 19% of the acreage was treated with ODM, directed primarily against aphids. Treatment for aphids is annually necessary in most areas, while mite treatments are necessary in more localized situations. ODM is applied on 'as needed' intervals, with 1 to 2 applications. Florida and Maryland reported only one application on 355 acres and 100 acres, respectively. Texas reported 1 to 2 applications on 31,00 acres. California and Oklahoma reported 2 applications on 17,407 acres and 2,428 acres, respectively. Little ODM is used generally in New Jersey, but they reported heavy use in 1987 due to severe aphid problems; and heavy use on melons in 1987 due to severe mite outbreaks. They feel that cucumber growers would be in serious trouble for mite control, should ODM and / or dicofol be lost by regulation. Most states reported a treatment dosage range of 0.25 to 0.5 lb AI per acre. Treatments commence on 'as needed' basis or when established threshold levels have been reached. New Jersey reported only ground applications; all others reported both ground and aerial applications, with no proportions given. Ground applications are by either boom or air blast sprayer at approximately 75 gallons per acre; ranging between 50 and 150 gpa for ground and 2 to 10 gpa for aerial (Anon., 1979). In states having large acreages, production is generally concentrated and cucurbits may not be in close proximity to other crops. In these usual cases, ODM applications are not in conflict with other crops or environmental situations. In areas of



mixed vegetable or other crop production, drift onto non-target areas is more likely. In ground application situations, producers have some control over off-target drift. The potential for drift is greater for aerial applications; adherence to state mandated buffer zones, where present, would greatly limit drift contamination. There is no evidence that off-target drift is any greater for ODM than for the alternative treatments.

There is no information relating to the rotation of cucurbits with other crops. Rotation is encouraged however, by diseases (anthracnose, leaf spot, mildews, and scab) which overwinter in crop debris. Rotation out of cucurbits also reduces bacterial wilt incidence, the bacteria overwintering in cucumber beetles. Such rotations, and the relatively modest usage of ODM in most cases, can be instrumental in reducing the development of resistance to this chemical. ODM usage on cucurbits is largely confined to selective applications for specific pest outbreaks, rather than as a broad-spectrum material used on a prophylactic basis. Few if any, instances of resistance have been reported.

### **Alternative Chemicals**

The chemical alternatives to Oxydemeton-methyl indicated by the responding states, are listed in Table 23. Seven alternatives for aphids and one for mites are listed mevinphos can be used on cucumber only, and dimethoate can be used on melons and watermelon only; and methamidophos can be used on cucumber and melons only. All states reported ODM equal or better than the alternatives for aphid control. New Jersey reported that methomyl, endosulfan and diazinon are preferred by growers, but indicated that broad-spectrum materials were chosen when aphids or mites were not the specific target pests. Texas reported that 37% of the cucurbits grown (84,300 acres) are treated with ODM because suitable alternatives are not available in specific instances. Oklahoma reported that 15% of the watermelon and cantaloupe (2400 acres) is annually treated with ODM because the alternatives (methomyl, parathion, dimethoate and mevinphos) are significantly more toxic to honey bees. Use of these alternatives result in significant bee kill, greater pollination costs, and reduced production. ODM is an extremely important tool in pest management during bloom periods (Cartwright, 1988). Three aphicide alternatives (mevinphos, dimethoate and parathion) are currently under special review by the EPA, and consequently their availability to producers cannot be assured. It is recommended that the re-registration status of alternative chemicals should be a major consideration in the benefits assessment process. Three states listed dicofol as alternatives for mite control. the relative efficacies of dicofol and ODM are not known. ODM is more toxic than dicofol to the applicator and workers.

Generally, the harvest intervals for the alternatives are no less favorable than for ODM, except for parathion which has 15 day intervals for cucumber and squash (Table 23). Assuming that all treatments require the same number of applications at the same rate, programs using ODM are more economical than methomyl; but more expensive than all other alternatives (Table 24). Because of the variability in reported costs, and price variability among distributors, it is difficult to make cost comparisons and subsequent generalizations. Given the specific uses of ODM on cucurbits however, cost differential would probably be a minor consideration in a producers decision. In Oklahoma for example, it was estimated that not having ODM at melon pollination, would result in 5% loss in production, or approximately \$159 per acre on 16,000 acres of melons (Cartwright, 1988).

Regarding toxicity to applicators or workers, methomyl and parathion are as toxic as ODM. No more people would be exposed to ODM than to any other alternative. Hand labor is used extensively, particularly during harvest. Perhaps fewer workers and applicators would be exposed to ODM than to alternatives, because ODM is not employed as a broad-spectrum treatment for protection against a variety of cucurbit pests (squash vine borer, squash bugs, cucumber beetles, leaf miners, flea beetles, melon worms, pickle worms, etc.). There is a 48 hr re-entry period for ODM - the probability of preproductive effects on workers could perhaps be lessened, by adjustment of the re-entry period.

The regulatory removal of ODM would probably not greatly affect the nationwide supply of cucurbits (except in the production of melons) in any given year. Effect on supply however, would be greatly dependent upon availability of alternatives, as three of the six alternatives for aphids control are in danger of being lost through regulation. If ODM should be lost, the end result could be more expensive cucurbits to the consumer, or a decreased supply that could result in greater importation of products from foreign sources; products perhaps treated with chemicals illegal for use in the US.

Table 17. Value of vegetables for fresh market and processing

Crop	1984	1985	1986
	-----in thousands of dollars-----		
<hr/>			
<u>Crucifers</u>			
broccoli <sup>a</sup>	237,884	239,345	227,242
brussels sprouts <sup>a</sup>	--	--	--
cabbage <sup>b</sup>	--	--	22,419
cauliflower <sup>a</sup>	174,931	169,133	188,534
<u>Cucurbits</u>			
cucumber <sup>a</sup>	103,823	123,639	112,922
mixed melons <sup>b</sup>	--	--	43,912
pumpkin/Squash <sup>b</sup>	--	--	21,180
cantaloupe <sup>b</sup>	--	--	106,947
watermelon <sup>b</sup>	--	--	21,878

<sup>a</sup>Source: Agricultural Statistics, 1987 (U.S. total).

<sup>b</sup>Source: Ivey and Johnson, 1987 (California only).



Table 18. Comparative efficacy of oxydemeton-methyl and other materials<sup>a</sup>

	Efficacy relative to oxydemeton-methyl <sup>b</sup>					
	Pot. <sup>c</sup>	Broc. <sup>d</sup>	Cuke <sup>e</sup>	Cab. <sup>f</sup>	Bean <sup>g</sup>	Bean <sup>h</sup> Lettuce <sup>i</sup>
malathion		1		1		
methamidophos 3				1		
endosulfan				1		
mevinphos				1		1
disulfoton				1		
methomyl				1		
dimethoate				1		
diazinon				1		
azinphos-methyl				1		
parathion				1		
permethrin				1		
chlorpyrifos				1		
naled				1		1
esfenvalerate				1		
dicofol				1		

<sup>a</sup>Source: Journal of Economic Entomology (1963-88), Insecticide and Acaricide Tests (1976-88).

<sup>b</sup>l=less effective, e=equally effective, g=greater effectiveness.

<sup>c</sup>green peach aphid (Tingey and Kim, 1976).

<sup>d</sup>green peach aphid (McCalley, 1976).

<sup>e</sup>melon aphid (Cartwright, 1985).

<sup>f</sup>cabbage aphid (Royer et al., 1988).

<sup>g</sup>two-spot mite (Stoltz, 1983a).

<sup>h</sup>flower thrips (Stoltz, 1983b).

<sup>i</sup>green peach aphid (McCalley and Der-I Wang, 1972).

Table 20. Alternatives to oxydemeton-methyl on crucifer crops

	No. states reporting chemical as alternative		Rate(AI)	PHI	Comments
	Aphids	Thrips			
acephate	1	-	0.5-1.0	14	caul. & Br. sp. only
diazinon	3	-	0.25-0.5	7	-
dimethoate <sup>a</sup>	4	1	0.25-0.5	7-broc. 7-caul.	- -
disulfoton <sup>b</sup>	2	1	1.0	3-cab. 30-Br. sp. 40-caul. 14-broc. 42-cab.	no. Br. sp. - - -
methamidophos <sup>b</sup>	4	-	0.5-1.0	35-cab. 14-Br. sp. 28-caul. 14-21 cab.	- - - -
methomyl <sup>b</sup>	1	-	-	-	NLA, aphids
mevinphos <sup>a</sup>	2	-	0.125-0.5	1-broc. 1-cab. 3-caul. 3-Br. sp.	- - - -
endosulfan	1	-	0.75-1.0	7-broc. 14-Br. sp. 7-cab. 14-caul.	- - - -

<sup>a</sup>Currently under Special Review by EPA.<sup>b</sup>Highly toxic (acute oral LD<sub>50</sub> = 100 mg/kg).

Table 21. Usage (\$/lb) of oxydemeton-methyl and alternative chemicals on crucifers

Chemical	KS	MI	CA	State		Mean
				FL	USDA	
oxydem.-methyl	6.00	8.00	7.00	6.88	12.70	8.10
acephate					8.73	8.73
diazinon	5.00		4.50		6.00	5.16
dimethoate		7.20	2.50		7.55	5.75
methamidophos		20.00	9.50	13.00	12.06	13.64
methomyl					13.60	13.60
mevinphos			3.50		6.34	4.92
endodulfan			6.50			6.50



Table 22. Oxydemeton-methyl usage on cucurbit crops<sup>a</sup>

State	No. acres grown	No. acres treated	Amount used	Target <sup>b</sup> pests
California	150,255	17,407	17,407	A
Texas	84,300	31,000	11,625	A
Florida	17,724	355	177	A,M
Oklahoma	16,650	2,428	2,418	A
Maryland	11,500	100	50	A
Indiana	10,000	730	411	M
New Jersey	8,500	2,850	2,625	A,M
Washington	4,900	1,270	1,270	A,M
Kansas	3,000	450	225	A
New York	800	190	70	A
TOTAL	307,629	56,780	36,278	

<sup>a</sup>Source: State replies to mailed surveys. Number of pounds used may only be best estimates of specialists.

<sup>b</sup>A = aphids, T = thrips, M = mites.

Table 23. Alternative chemicals to oxydemeton-methyl on cucurbit crops

Chemical	No. states reporting chemical as alternative		Application rate	PHI	Comments
	Aphids	Thrips			
methomyl <sup>a</sup>	5	-	0.45-0.9	3	tox. to bees <sup>b</sup>
diazinon	5	-	0.5-0.75	3	-
endosulfan	7	-	0.5-1.0	0	-
mevinphos <sup>c</sup>	6	-	0.125-0.25	1	tox. to bees <sup>b</sup> cukes only
dimethoate <sup>c</sup>	5	-	0.25-0.5	3	tox. to bees <sup>b</sup> melon & water only
parathion <sup>a,c</sup>	2	-	0.25-0.5	15 7 10 15	cuke melon pumpkin squash tox. to bees <sup>b</sup>
methamidophos <sup>a</sup>	1	-	0.5-1.0	7	cuke & melon tox. to bees <sup>b</sup>
dicofol	-	3	1.5 max.	2	safe on bees

<sup>a</sup>Highly toxic (acute oral LD<sub>50</sub> 100 mg/kg).

<sup>b</sup>Relative to oxydemeton-methyl.

<sup>c</sup>Currently on Special Review by EPA.

Table 24. Cost (\$/lb) of oxydemeton-methyl and alternative chemicals used on curcubits in individual states

Chemical	CA	FL	IN	KS	MD	NJ	NY	OK	WA	USDA*	MEAN
oxydem.-methyl	7	6	17	6	19	20	11	17	24	12	14
diazinon	5	-	-	5	13	-	-	10	-	6	8
dicofol	-	-	8	-	-	-	-	-	-	12	10
dimethoate	3	-	-	-	20	14	-	8	-	8	10
endosulfan	7	13	-	10	1	18	-	10	-	-	12
methomyl	-	-	-	-	13	-	-	22	-	14	16
mevinphos	4	16	-	-	9	-	19	-	-	6	11
parathion	-	7	-	-	-	-	-	8	-	5	7

\*Source: USDA Summary.

Table 25. Summary of application methods and procedures for oxydemeton-methyl usage for control of aphids and thrips on cruciferous crops

Formulation:	2SC	
Package size:	2 and 5 gallon cans	
Equipment: <sup>a</sup>	aerial and ground	
Pct. applied by air: <sup>b</sup>	ca. 95%	
Rate of application: <sup>a</sup>	0.25 to 0.5lb ai/acre	
Carrier: <sup>b</sup>	water	
Avg. no. applications: <sup>a</sup>	1.5 per crop	
Season: <sup>a</sup>	spring, summer, fall	
Stage of growth: <sup>b</sup>	2-3 wks. after transplant onward	
	Air	Ground
Speed of sprayer: <sup>b</sup>	50 mph	3-4 mph
Avg. gallons/A: <sup>b</sup>	2 (2-10)	75 (50-150)
Tank capacity: <sup>b</sup>	120 (80-220)	150
Refill Time: <sup>b</sup>	3-8 min.	5-10 min.
Lb/in. <sup>2</sup> : <sup>b</sup>	avg. 100	
Droplet size: <sup>b</sup>	200-400 microns	>400 microns
No. hr/day spraying: <sup>b</sup>	3-5	4-6
Time actually spraying: <sup>b</sup>	30-50% overall	ca. 50% overall
Avg. no. acres treat./hr.: <sup>b</sup>	70-120	3-4
Nurse tank if used: <sup>b</sup>	500-1,000 gal	
Capacity of transfer system: <sup>b</sup>	open: 40-50 gal/min. closed: 20-25 gal/min.	
No. acres treated: <sup>a</sup>	192,143	
Acre-treatments: <sup>a</sup>	288,215	
No. pounds applied: <sup>a</sup>	105,469	
Avg. acres/farm: <sup>b</sup>	174 (Calif.)	
% crop treated: <sup>a</sup>	ca. 90%	

\*Source: Mail surveys of extension and research specialists.

<sup>b</sup>Source: Anonymous, 1979. Data presented are for broccoli; it is assumed that parameters for all crucifers would be likewise.





## OXYDEMETON-METHYL USE ON ALFALFA

Ben Simko, Oregon State University  
William A. Brindley, Utah State University

United States alfalfa seed production is concentrated in California and the other western states of Idaho, Washington, Nevada, Oregon, Montana and Utah. Minor and erratic "catch crop" seed production does occur in the Great Plains region including Oklahoma, Kansas, Nebraska, South Dakota and North Dakota. However, the far west dominates in management intensive, technologically advanced alfalfa seed production. This dominance is attributed to several factors: 1) Arid climates suitable for pollinating bees and seed harvest; 2) conducive soils; and 3) dependable and relatively low cost irrigation water supplies. A highly competitive infrastructure comprised of specialized growers, seed conditioners, private alfalfa breeding firms has developed, tapping the favorable natural resources that exist in areas of the western U.S.

The strategic importance of the seed industry infrastructure to U.S. forage production needs to be emphasized. Estimates for 1987 from USDA-NASS ranked alfalfa hay as one of the top U.S. commodities both in area of production, 25.5 million acres, and value of production 5.61 billion dollars (Table 26).

The alfalfa seed component supports a large forage industry. Alfalfa hay crops must be replanted periodically to achieve maximum yield and quality. Seeding rates vary, but can require as much as 20 lbs of alfalfa seed per acre of hay. This support comes not only from supplying common seed but from supplying a high quality seed of genetically improved varieties adapted to all the important areas of forage production. Over 150 improved varieties have been developed with unique winter hardiness and pest resistance characteristics. Seed of all of these varieties are produced in the west and marketed throughout the nation. All of the major alfalfa breeding firms have research and seed production operations in the west including Northrup King, Pioneer Hybrid, AgriPro, and W.L. Research.

California is the largest seed producing state in the U.S. and produces alfalfas for the non-hardy, semi-hardy and winter-hardy markets. The northwest is second in overall production but dominates in the production of semi hardy and hardy types of alfalfas. Table 27 summarizes recent seed production statistics and Table 28 reveals the scope of the seed infrastructure in the west.

The size of the alfalfa seed industry is relatively small - 150,000 acres in the major production states produced roughly 80 million lbs. of seed. Nationwide around 93 million lbs. of seed was produced in 1988 with a farm gate value of around \$100 million.

But the strategic importance of the commodity in providing a reliable, efficient source of improved alfalfa varieties to U.S. agriculture should not be overlooked. In any assessment of ODM, trichlorfon, mevinphos and naled in alfalfa production systems, this strategic factor should be included in the overall risk benefit equation.



Table 26. Recent U.S. forage alfalfa statistics\*

U.S. Alfalfa and Alfalfa Mixture for Hay

<u>Year</u>	<u>Acres</u>	<u>Average Yield T/A</u>	<u>Production Tons</u>
1985	25,608,000	3.32	85,048,000
1986	26,793,000	3.42	91,552,000
1987	25,485,000	3.32	84,554,000

Estimated Production Value of Alfalfa and Alfalfa Mixture Hay

<u>Year</u>	<u>Production Tons</u>	<u>Average Price</u>	<u>Total Value</u>
1987	84,554,000	\$66.40	\$5.6 billion

Alfalfa Ranks as a Top U.S. Commodity

1 - Corn (grain)	\$12.1 billion
2 - Soybeans	\$10.4 billion
3 - Alfalfa	\$ 5.6 billion
4 - Wheat	\$ 5.4 billion
5 - Cotton	\$ 4.6 billion

\*Derived from USDA NASS data

Table 27. 1988 U.S. Alfalfa Seed Production\*

Regular Production States

<u>State</u>	<u>Acres Harvested</u>	<u>Yield Per Acre Lbs.</u>	<u>Production Clean Lbs.</u>
California	69,000	599	41,320,000
Idaho	35,000	475	16,625,000
Washington	26,000	450	11,700,000
Oregon	10,000	475	4,750,000
Nevada	9,500	500	4,750,000
Total	149,500		79,145,000

Variable Production States

<u>State</u>	<u>Production Clean Lbs.</u>
Montana	2,500,000
North Dakota	1,000,000
South Dakota	5,000,000
Nebraska	1,250,000
Kansas	4,000,000
Total	13,750,000

\* Statistics from California Crop Reporting Service, Seed Certification Agencies and industry sources.

Table 28. Alfalfa seed infrastructure in California and the Northwest<sup>a</sup>

State	Number of Growers	Number of Companies <sup>b</sup>
California	125	17
Idaho	600	12
Washington	95	7
Oregon	100	5
Nevada	30	2
Montana	100	20
Total	1,050	63

<sup>a</sup>Source: NAPIAP survey, Fall 1988.

<sup>b</sup>Combined total of companies conditioning and/or marketing alfalfa seed.

## Pest Management

Production of alfalfa seed is a highly specialized and management-intensive enterprise. Three essential components of management include: 1) control of detrimental insects; 2) supply of effective bee pollinators; and 3) skillful application of irrigation water when alfalfa plants are flowering. In the western production areas control of detrimental insects is accomplished through integrated pest management systems. In 1973 Washington State University Extension Service initiated a highly successful alfalfa seed IPM project. Similar programs were started by Oregon State University, University of Idaho, and University of Nevada Extension Services in 1976. University of California Cooperative Extension has developed programs unique to the south San Joaquin Valley production area.

Particularly in the northwest region, the basic objectives of training pest management personnel, implementing improved pest control programs and turning IPM services over to the private sector have been achieved. A truly unique feature of the IPM systems is the development of monitoring techniques and improved management procedures for the essential bee pollinators.

Alfalfa seed IPM systems include the classic components of 1) weekly sampling to monitor pest and beneficial insect populations, 2) use of research derived economic thresholds, 3) conservation of beneficial insects and 4) selective use of pesticides. A 1988 survey of growers and seed company fieldmen in Idaho, Washington, Oregon and Nevada revealed nearly 100% continue to practice some form of IPM on their farms. Prior to the development of IPM programs in the northwest it was not uncommon for seed fields to receive 8-10 applications of insecticides per season. Now IPM growers typically apply 1-5 insecticide treatments per year. Grower adopted IPM methods have resulted in 1) better timing of applications based on accurate counts of various stages of the pests, 2) reduced disruption and increased utilization of beneficials, 3) elimination of unnecessary treatments and 4) improved conservation of pollinators.

Alfalfa Seed IPM systems are continually being refined due to the ongoing efforts of university researchers, extension personnel, seed company fieldmen and consultants. IPM technology transfer reaches growers through an effective information network including 1) annual regional and local commodity meetings, 2) seed company meetings, and 3) newsletters and extension publications. The success of IPM on this commodity is in serious jeopardy due to the crisis of pesticide registration and re-registration on a minor use crop such as alfalfa seed. Table 29 summarizes the registration record of alfalfa seed during the period 1978-1988. Loss



of registration of pirimicarb and demeton, two selective aphicides has seriously strained IPM on alfalfa seed. The short residual organophosphates, ODM, naled, mevinphos and trichlorfon are currently the cornerstones of the insecticide component of pest control in Northwest seed production. They provide the short residual control of primary and certain secondary pests during the flowering period when pollinators are active.

The loss of these compounds due to the economics of re-registration or for toxicological reasons would devastate alfalfa seed IPM in the northwest region.

Table 29. Northwest alfalfa seed pesticide registrations from 1978 to 1988\*

Cancellations	New registrations	Special review in progress
		carbofuran
<b>Insecticides</b>		
pirimicarb	chlorpyrifos	oxydemeton-methyl
femeton	permethrin	naled
toxaphene		mevinphos
		trichlorfon
		parathion
<b>Acaricides</b>		
chlordimeform		
<b>Herbicides</b>		
chlorthal	sethoxydim	
dimethyl		
chlorpropham	bromoxynil	
simazine		
hexazinone		
<b>Dessicants</b>		
dinoseb		

\*Section 18 Emergency Registrations not included.

### Impact on Pollinating Insects

Alfalfa must be cross pollinated to produce commercial amounts of good quality seed. Insect pollination is the only important method by which cross pollination occurs. There are three principal pollinators of alfalfa seed. Honey bees are used almost exclusively in California. Growers in the northwest alfalfa seed producing areas depend almost entirely on two species of wild bees, the alkali bee, Nomia melanderi and the alfalfa leafcutting bee, Megachile rotundata. Table 30 reveals the relative importance of the three bees in the principal production regions. About one-third of all seed production in the U.S. and more than three-fourths of all seed of hardy alfalfa varieties is dependent on the two wild bees.

In California a minimum of 4 to 5 strong honey bee colonies per acre is recommended. However since only small amounts of ODM, naled, mevinphos and trichlorfon are currently being used in this state the impact of these insecticides on pollination management is inconsequential.

In the Northwest the situation is very different. Honey bees do not pollinate alfalfa to an economic level. The two wild bees, the alkali and the alfalfa leafcutting bee, though solitary will nest gregariously and are oligolectic on alfalfa. They are very efficient pollinators of alfalfa.

Since their initial description and adaptation to alfalfa seed production 3-4 decades ago they have gradually become semi-domesticated bees. Management techniques have been developed which integrate the biology of the two species with overall seed production systems. Today a multi-million dollar industry is built around providing nesting materials, domiciles, predator and parasite traps and the raising of the two bees, particularly the alfalfa leafcutting bee.

The use of these pollinators has increased yields 3 to 5 fold, and 1,000 lbs. per acre seed yields are not uncommon. The success and survival of the northwest alfalfa seed industry is dependent on the alkali and leafcutting bee.

The alfalfa leafcutting bee nests in small holes drilled in wooden boards or other suitable nesting material. The bee boards are stacked in small buildings or domiciles which are placed directly in fields during the pollination period. Flowering occurs from mid-June to mid-August with peak pollination activity usually in July. The life span of the female leafcutting bee is about 5-6 weeks. Synchronizing the life cycle of the bee with the bloom period of alfalfa is extremely critical to produce an economically viable seed crop. During the bloom period the bees develop a strong orientation to the fields in which they are nesting. Movement of the domiciles during this critical period is disruptive to bee orientation and can result in loss of bees, reduced seed set, and lower yields.

For these reasons it is not generally practical to protect bees from required insecticide treatments by moving domiciles out of the fields until the chemicals degrade to safe levels. Growers maintain leafcutters as essentially resident, fixed populations in fields or clusters of fields. To make this successful growers must avoid treatments with longer residual insecticides hazardous to pollinators.

Current university recommendations suggest maintaining 7-10 thousand female leafcutting bees per acre to optimize yields. Grower inputs for bees and handling costs can reach as high as \$173/ac. and represent 32% of the total per acre cost.

Alkali bees are used primarily in the Gardena-Touchet region of Washington and in Nevada. The alkali bee is the most effective pollinator of alfalfa seed of the three types of bees currently used. However, it is also the most difficult to manage. They are soil nesting bees with rigid requirements for soil texture, moisture and salinity. These bees are managed in natural or artificial bee beds located adjacent to seed fields. They obviously can not be moved to avoid hazardous insecticide treatments. The availability of short residual, safe, insecticides is essential in the production areas that have adopted this pollinator. Alkali bee beds with 1 million nesting females per acre can provide excellent pollination for nearly 200 acres of alfalfa. In the Gardena-Touchet area, cost for managing alkali bees is around \$10/ac.

Two of the three essential management components of seed production, control of insect pests and supply of effective pollinators, sets up a serious dilemma for the seed producer. How can the alfalfa seed grower control seed-destroying pests while maintaining an adequate pollination force required for economic yields? The delicate balance is being struck by using IPM methods and selective short residual insecticides, ODM, naled, mevinphos and trichlorfon. These four compounds are all being used cautiously to control pests during the critical flowering period. Treatments are applied exclusively after sunset or at night when the pollinators have generally returned to their domiciles or soil nest. The short residual properties of these chemicals reduces the hazards to the bees working the next day to acceptable levels (Table 30). Loss of registration of pirimicarb and demeton, two relatively bee safe selective aphicides has placed a strain on pollinator-pest management systems. The cumulative loss of ODM, naled, mevinphos and trichlorfon without replacement with materials of similar selectivity and bee safety would have grave consequences for the northwest alfalfa seed industry. Table 32 summarizes characteristics of the insecticides in relation to the alfalfa leafcutting bee and the alkali bee.



Table 30. Relative importance of pollinator species in alfalfa seed production\*

State/Region	% of production dependent on bee species		
	Honey bee	Alfalfa leafcutting bee	Alkali bee
California	99	1	0
Idaho/Oregon	0	99	1
Washington			
Gardena/Touchet	0	30	70
Columbia Basin	0	97	3
Nevada	5	75	20
Montana	0	100	0

\*Source: NAPIAP Survey, Fall 1988.

Table 31. Mortalities of alkali bees (AB), and alfalfa leafcutting bees (LB) exposed to 12 hour residues of insecticides\*, Washington State University, Prosser, WA 1988

Insecticide	Concentration (lbs ai/A)	% mortality after 24 hrs <sup>b</sup>	
		AB	LB
trichlorfon	1.0	6	5
oxydemeton-methyl	0.75	27	2
naled	1.0	0	18
mevinphos	0.5	10	6

\*Data from "Integrated Pest and Pollinator Investigations" 1988 D.F. Mayer, J.D. Lunden, E.R. Miliczky, Department of Entomology, IAREC, Washington State University.

<sup>b</sup>Bees caged with treated foliage.

Table 32. Toxicity of pollination (bloom) period insecticides to wild bees\*

Insecticides	Application rate (lbs ai/A)	Length of residual toxic effect (hrs)		Comments
		Leafcutting bee	Alkali bee	
naled	0.75	12	12	Not generally recommended as bloom treatment because of bee hazard! Under special environmental conditions it is used during pollination period.
trichlorfon	0.5-1.0	2-5	6-14	Less effective to control 1/ pest lygus bug due to resistance. Used for lepidopterous pest.
mevinphos	0.25-0.5	<5	<5	Toxicity Level I to applicators. Primarily late season use against lygus.
oxydemeton-methyl	0.5	<4	<2	Bee safe, effective against lygus bug early season.

\*Source: How to Reduce Bee Poisoning from Pesticides (1988).

### Comparative Performance Evaluation

Management of detrimental insect populations is essential to successful alfalfa seed production. Lygus bugs are the most serious pests of alfalfa seed and considered primary pests in California and the northwest. Two principal species are involved: Lygus elisus and L. hesperus (Hemiptera:Miridae), of which both the immature nymphs and adults feed on alfalfa. There are several types of injury produced by feeding lygus bugs. They have sucking mouth parts and physically damage the plant by puncturing the tissue and sucking the plant juices. There is also a toxic reaction from the saliva of the insect. Greatest damage is caused when lygus bugs feed on the flower buds. Injured buds turn tan to white, die and fall from the plant within 2-5 days. Lygus bugs also feed on immature seeds. The pod is pierced and the juices are sucked from the developing seed. Seeds turn brown, later nearly black, shrivel and will not germinate.

Most lygus bug damage and potential crop yield loss occurs during the critical flowering and early pod development stages. This coincides with maximum pollinator activity in the fields. In the northwest control of lygus bugs is achieved with treatments of ODM, naled, mevinphos, or trichlorfon. All of these insecticides are sprayed after sunset to reduce bee mortality to a minimum. Unfortunately, there are no effective control measures for lygus bugs on alfalfa seed except for insecticides.

Secondary pests that also cause damage during the flowering-pollination period include aphids, loopers, armyworms, cutworms and spider mites. Table 33 summarizes primary and secondary alfalfa pests during the flowering-pollination period of the crop.



The four insecticides under review are all valuable insecticides tools in an overall IPM approach to alfalfa seed production. Each has advantages, disadvantages, and unique properties which impart the selectivity needed in making difficult treatment decisions. The comparative efficacy of these insecticides cannot be evaluated in a vacuum one against another, for a single pest species. Rather their relative utility must be judged in the context of a complex pest-pollinator management system with its subtle overlay of environmental factors. Treatment decisions in alfalfa seed IPM, particularly during the flowering-pollination period, include several considerations:

1. Primary pest levels and thresholds.
2. Secondary pest levels and thresholds.
3. Species of pollinating bee utilized.
4. Pollinator density and bee age.
5. Levels of beneficial insects.
6. Stage of crop development, i.e. early flowering, late flowering, early pod development.
7. Irrigation scheduling.
8. Method of application, ground or air.
9. Evidence of pest population resistance to insecticides.
10. Weather conditions, including wind velocity, night time temperatures, relative humidity and presence or absence of dew on canopy.

For example, ODM is frequently used as the first bloom treatment against lygus bugs but it loses some efficacy against lygus as the season progresses. Later season lygus treatments of mevinphos or naled are common but warm evening temperatures and absence of dew on the canopy are critical to avoid bee kills. Trichlorfon is the primary lygus treatment in Montana, but resistant populations of lygus in the other Northwest states has reduced its use significantly. Trichlorfon is however a selective bee safe treatment against secondary lepidopterous pests throughout the northwest. ODM does provide some suppression of spider mites but is not effective for controlling occasional outbreaks of loopers or armyworms. There are differences among the four insecticides with regard to impact on beneficial insects. None of the four insecticides can control outbreaks of the spotted alfalfa aphid.

The factors of field status, pest outbreaks, weather condition and other treatment considerations vary not only from season to season but week to week. The availability of insecticidal products with different efficacy against the spectrum of pests present with alternative modes of action, routes of detoxification, residual life, and possibility for use with reduced impact on beneficials is critical to a successful IPM approach. Table 34 compares the available insecticides for the flowering-pollination period.

Suppression of lygus bugs as well as other secondary pests is essential to achieve economic yields. Control of detrimental pests can enhance yields 5-10 fold. Interaction of lygus control and seed yield has been well documented by researchers since the late 1950s. Two recent research projects clearly exhibited the relationship between pest suppression and yield. Data in Table 35 reveal how even a single treatment of ODM during the flowering period increased yield by more than 50%. This represents nearly a \$160/ac. jump in the value of production. No other pest control treatments were applied on these replicated experiment station plots during the course of the experiment.

A total alfalfa seed management study, conducted by Oregon State University researchers from 1985-1988, give further evidence of the yield benefits of IPM. IPM under two irrigation regimes yielded 3.8X and 2.7X higher production over the untreated control (Table 36). Both Naled and ODM were applied to suppress lygus and aphids in this study.

Table 33. Primary and secondary insect and mite pests of Northwest Alfalfa seed during flowering - pollination period\*

Common name	Scientific name	Comments
<b>Primary Pests</b>		
lygus Bug	<u>Lygus elisus</u> <u>Lygus hesperus</u>	Stresses plants, damages flower buds, flowers and developing seed. Progressively more difficult to control during course of season. Must be treated 1-3 times per season.
<b>Secondary Pests</b>		
pea Aphid	<u>Acyrtosiphon pisum</u>	Found in all production areas. Heavy infestations stunt and wilt plants. Large amounts of honeydew produced. Can cause premature flower drop. Exceeds treat threshold usually once per season.
blue alfalfa aphid	<u>Acyrtosiphon kondoi</u>	Newly introduced aphid in northwest. Similar damage as pea aphid but more severe at lower numbers. Only occasionally needs treatment.
spotted alfalfa aphid	<u>Therioaphis maculata</u>	Found in all production areas. Secretes plant toxin while feeding. 20-40 aphids per plant can cause severe injury. Produces large amounts of honeydew. Susceptible alfalfas usually treated once or twice per season.
alfalfa seed chalcid	<u>Bruchophagus roddi</u>	Tiny wasp, larvae of which consume seed contents. Difficult to control with insecticides. Cultural controls key. Some evidence adult control with OPs may help.
alfalfa weevil	<u>Hypera postica</u>	Larvae chewing defoliators and bud destroyers. Common prebloom pest. On rare occasions late hatch causes problem during flowering.
loopers, armyworms, cutworms	<u>Trichoplusia ni</u> <u>Mamestra configurata</u> <u>Spodoptera sp</u> <u>Euxoa sp.</u>	Occasional localized outbreaks can be severe. Cyclical outbreaks every 5-7/yr. Defoliates and clip off flowers and pods. Late instars very difficult to control.
spider mites	<u>Tetranychus urticae</u> <u>Tetranychus pacifica</u>	Stippling damage on leaves and buds. Heavy infestations stress plants and webbing interferes with pollination. Usually late season pest near end of pollination period. Usually treated once per season every other year.
grasshoppers	Several species	Cyclical outbreaks every 7-10 years.

\*Source: Alfalfa Seed Insect pest Management (WREP 0012, May 1979).



Table 34. Effectiveness of insecticide used in the Northwest during the period from flowering to pollination

	Application rates (lbs ai/A)	Efficacy on Lygus bugs	Efficacy on other pests	Impact on beneficials	Other advantages or disadvantages
oxydem-methyl	0.375-0.5	Excellent early season, good to fair late season	Good on pea aphid; some mite suppression.	Moderate	Systemic action; relatively
naled	0.5-1.0	Very good late season grasshopper;	Good on fair on lepidopterous pests.	Severe	High bee risk; monitoring of weather conditions important when applying
mevinphos	0.25-0.5	Very good late season grasshopper; fair on alfalfa weevil; moderate on chalcid	Good on severe	Very	Relatively safe on bees. High applica-
trichlorfon	0.5-1.0	Poor except in Montana and other select areas	Very good on small lepidopterous pests	Moderate bee safe; Resistance problem with lygus.	Relatively
permethrin (1988 reg.)	0.1-0.2	Inconsistent on	Inconsis- severe aphids	Very	Mite outbreaks following treatment; High risk of bee kills

Table 35. Interaction of 3 day post treatment lygus control with seed yields, Malheur Experiment Station, 1985<sup>a</sup>

Treatment	Application rate (lbs ai/A)	% Lygus controlled	Seed yield (lbs/A)	% of check yield
oxydem.-methyl	0.5	92.4	358	155
trichlorfon	1.0	58.7	269	116
untreated check	--	--	231	100

<sup>a</sup>Source: Dr. Clint Shock, Malheur Experiment Station Superintendent and Ben Simko, Malheur County Extension Agent (unpublished data).

Table 36. The effects of insecticide control levels and irrigation stress on Wrangler alfalfa seed production. Malheur Experiment State University, Ontario, Oregon 1988<sup>a</sup>

Water regime	Insect control	Seed yield (lbs/A)				Mean
		1985	1986	1987	1988	
Nonstressed	None	138	167	16	51	93
	IPM	252	828	65	255	350
	Weekly	214	902	138	379	408
	Average	201	632	73	228	284
Stressed	None	272	195	58	201	182
	IPM	482	667	242	593	496
	Weekly	564	759	667	642	658
	Average	440	540	323	479	446
Combined	None	205	181	37	126	137
	IPM	367	747	153	424	423
	Weekly	389	830	402	510	533
Overall Mean		320	586	198	354	365
LSD <sub>.05</sub> for Irrig. Stress		62	69	104	45	
LSD <sub>.05</sub> for Insect Control		41	48	68	64	
LSD <sub>.05</sub> for Irrig. x Insect Control		68	68	79	91	

<sup>a</sup>Source: Clint Shock and Bill Stephen, Department of Entomology, Ohio State University; pending publication as O.S.U. Agricultural Experiment Station Special Report.

### Potential for Pesticide Resistance

The main pest of alfalfa seed in the northwest is the western legume bug, lygus bug, Lygus hesperus. While other species are present in the fields of Utah, Idaho and Oregon, L. hesperus is the species we have concentrated upon. Lygus elisus proportions tend to increase with presence of weeds in the fields or at the field borders.



Alfalfa seed growers of Oregon and Idaho, and the Delta, Utah region, have complained of possible resistance of lygus bugs to trichlorfon for a number of years. These problems are a major factor in the fall of trichlorfon from once the most preferred to now one of the least-used insecticides in northwestern alfalfa seed production (Table 40). We have confirmed that resistance has developed by these methods: 1) comparison of trichlorfon efficacy by bioassay of regions of no and high insecticide use; 2) correlation between LC50 and efficacy of trichlorfon on field plot trials by ground-spray rigs; 3) finding that DEF, an effective inhibitor of esterases, markedly lowers trichlorfon LC50 values; 4) correlating trichlorfon LC 50 values to esterase activity.

**Developing Tests for Resistance:** Our concern has been that effective control of lygus bugs on alfalfa seed crops is only feasible with effective, short-lived, insecticides that spare most beneficial arthropods. It is particularly important that the pollinators be spared since they must be kept in the fields at the same time much of the lygus bug control is effected. Too many of the alternative insecticides, pyrethroids or the more toxic organophosphates for example, are likely to be damaging to leafcutting, alkali, or honey bees. Considerable economic and labor investments are made in these pollinators. Few insecticides meet all of these criteria and loss of them by either resistance or regulatory decision would place the alfalfa seed industry in serious difficulty.

Each step of the confirmation process has therefore included field studies in Utah, Idaho or Oregon and laboratory studies at Utah State University of field-collected samples of Lygus hesperus. Care has been taken to design methods that are not only meaningful for laboratory research, but which can also be used directly in the field. Because of the well-organized IPM systems for alfalfa seed production the northwest (Section II), we felt the economic role of trichlorfon and other insecticides used on the crop would be optimized if growers had, before spraying, baseline data and convenient methods to estimate possible resistance and probable efficacy. Application of these methods would enhance the economic return with use of the insecticides while minimizing environmental and exposure impacts.

The research has been successful. We are ready to recommend methods for IPM surveillance which include 1) bioassay, 2) bioassay with synergism, 3) spot tests for the resistance-conferring esterases of L. hesperus, or 4) combinations of esterase tests and synergism.

**Biological Assays and Synergism:** The purpose of the bioassays is to provide a quantitative estimate of the degree of susceptibility, tolerance, or resistance of the lygus bug population. The data are represented as LC (lethal concentration) values to kill a particular percentage of pests sampled. The LC50, the amount of insecticide required to kill half of the population sample, is the most commonly used LC value. Bioassays are the most demanding of these steps. They require a portable incubator (easily built for less than \$150) (Brindley et al., 1981) and a kit of pre-coated glass vials (Brindley, 1975) or disposable "zip-lock" bags. If the bags are used, we estimate the cost of one bioassay kit to be about \$1 and hence easily disposable. The recommended bioassay period is 8 hours. The bioassay with bags works well with trichlorfon and ODM and has possibilities with naled. The possible alternative insecticides, permethrin, baythroid and bifenthrin also work well in the bags.

Bioassay with synergism requires two extra sets of vials or bags, extra sampling, and another hour. The only variation is that half of the insects sampled are subjected to a regular bioassay and the other half are first exposed to a chemical (synergist) which might inhibit or block a resistance mechanism, and if that mechanism was solely responsible for the resistance, the LC50 value observed should be similar to that of a susceptible population. If the resistance mechanism indicated by the synergist is important but there is another mechanism as well, the new LC50 will be lowered but not lowered to the level of a susceptible population.



The bioassay kits therefore give the alfalfa seed IPM system a means of not only estimating the magnitude of resistance but also of calculating estimates (Brindley and Selim, 1984) of the reason for the resistance. This gives those wishing to optimize the economic advantages of insecticide use of a simple, practical, yet sophisticated tool for characterizing their populations before spraying begins.

**Spot Tests for Esterases:** The bioassays and synergism, confirmed by laboratory biochemistry, show that *L. hesperus* resistance to trichlorfon is due to enzymes called esterases. This is a common resistance mechanism against organophosphate insecticides. We have no evidence that other detoxication systems (MFOs, GSTs) are involved. As will be explained later, a strain of *L. hesperus* which has higher esterase levels plus a form of acetylcholinesterase (the enzyme attacked by organophosphates as the insect is killed) which resists poisoning, has now become a factor in alfalfa seed protection.

Spot tests for esterases require no incubator and can be accomplished with small, inexpensive kits. Lygus bugs caught in the field are frozen with dry ice and crushed between two filter papers. The filter papers had been treated previously with a chemical that will be attacked by esterases inside the lygus bugs. If the esterase level is high, when a proper dye is placed on the crushed insect, a definite color change will appear. The color readings are taken from one piece of the filter paper; the other filter paper can be returned to a laboratory for more detailed analyses by biochemical methods if that is desired. The spot test takes ca. 15 minutes to complete and, with modest care, can be done at the field site or later with frozen (or even dried) samples of lygus bugs.

As with the bioassays, synergism can be used with the spot tests. Half the population sample is pretreated with the synergist DEF and the spot test is performed on both the pretreated and regular insects. If the color changes upon addition of the dye to a crushed, pretreated insect, that insect probably was of the new, combined, resistance form. We would caution readers that these data are preliminary, though based on a lot of experience, and the final verdict will be rendered in the near future.

There are three important advantages of the spot tests. First, they are more rapid and secondly they are less expensive. But, of greatest importance is that they improve sampling and statistical efficiency by providing data from each individual. Thus, the proportion of each response type (susceptible, resistant, highly resistant) can be estimated in the populations. Theoretical models of how resistance changes with cultural and ecological factors in agriculture generally rely upon the numbers of pests and the proportion of resistant or susceptible individuals. This gives a good connection point between practice and theory. Biological assays, on the other hand, are estimates drawn from populations and not from individuals. They require much more sampling but tend also to give the "bottom line" in terms of toxicity. There are fewer correlations that are necessary to use bioassay data effectively in resistance management. If sampling efficiency is a major barrier, bioassays can be simplified to "discriminating assays" to reduce sampling needs.

**Impact of Resistance Detection upon Economics of Insecticide Use:** The economic advantages of trichlorfon and other insecticides could be enhanced by resistance-detecting methods. IPM firms could base their decisions for insecticide applications on reliable data. Wasted applications of insecticides, unnecessary selection pressure toward higher resistance levels, incorrect selection of alternative insecticides, and extra disruption of biological control agents could be lessened.

Insecticide recommendations could be better tailored to local conditions, emergence of new strains of resistant pests could be more readily detected, and grower awareness of the resistance problem would be increased if tests for resistance were part of IPM programs. There would be added incentive for determining resistance levels in beneficial, natural enemies of pests and for keeping detailed records of insecticide application histories. Failures of



insecticides due to errors in application would be more readily identified as such. There would be quantitative criteria to judge rates of resistance development or spread.

Status of *Lygus hesperus* Resistance in Utah, Idaho, Oregon: The best approach for integrating resistance detection into alfalfa seed IPM would be for IPM field scouts to test weekly collections by the spot test or the spot test plus synergism. IPM firms or Extension persons could then conduct periodic bioassays or bioassays with synergism, matching these data to pre- and post-application pest and beneficial insect counts. In the case of trichlorfon, declining efficacy can be expected with LC50 values exceeding 1 microgram trichlorfon/vial or when the percent of insects showing a positive color reaction on the spot test papers exceeds 10. The disposable bag bioassay is a newer method but it appears that the threshold for efficacy with Trichlorfon is ca. 4 micrograms trichlorfon per bag. If *Lygus hesperus* populations are susceptible to trichlorfon, adequate control can be achieved with less than 1 lb ai/acre; if resistance has been established, not even 3 lb ai/acre will suffice. If the LC50 values have increased from 1 ug to 2 ug trichlorfon per vial, application of the insecticide will not give a fully optimal, economic, return. A "resistance factor" of only 2 may seem implausible but it is real.

*Lygus hesperus* resistance can be very localized and prior testing is necessary. Regional generalizations are difficult to rely upon. For example, we have found adjacent fields, cultivated by the same grower, with LC50 values of 1 ug/vial on the one hand and 9 ug/vial on the other. Field efficacy trials and esterase tests matched the bioassay conclusion. Such local variations may help explain why some growers in apparent resistance areas still use trichlorfon. Another possibility is that early in the season, or in fields within the migration range of *Lygus hesperus* from drying range plants, there can be decreases in the frequency of resistant individuals. Fields more closely exposed to immigrating susceptible lygus bugs may thus have enough susceptible insects to bring populations below the economic threshold with an insecticide that could be ineffective later in the season or located to be less likely to receive susceptibles. Local differences are responsible, in part, for ranges in LC50 values found *Lygus hesperus* populations (Table 37).

Table 37 illustrates three time periods of bioassay trials for trichlorfon with *Lygus hesperus*. Regional differences (Utah: general susceptibility, Oregon/Idaho: general resistance) are apparent. Growers reports, interestingly enough, have proved quite accurate. Generally speaking, our toxicology measurements have matched grower experience and IPM records.

The data of Table 37 indicate a further problem, however. Notice the extremely high LC50 values for Trichlorfon (bag assay) data collected in the summer of 1988. Through the summer of 1987 IPM managers found more naled had to be used to be effective. By fall, 1987, in a field near Nampa, Idaho, a full-rate application of naled failed. We analyzed that circumstance by trichlorfon bioassays and synergism. Even though the insecticide sprayed and the insecticide used for analysis were different, it was clear that a change may have taken place in the *Lygus hesperus* population. We now have evidence that a new resistance mechanism has appeared. It is possible that higher levels of carboxylesterases and of acetylcholinesterases resistant to inhibition by paraoxon. If those indications are correct, it will be disturbing for organophosphate usage as combinations of metabolic (as esterases) and target site (as acetylcholinesterases) can be very difficult. Synergism bioassays also indicate a new trend in resistance.

Alternative Insecticides: Bioassays were conducted in 1988 on trichlorfon and five alternative insecticides, so that baseline data in Utah, Idaho, and Oregon are being accumulated for trichlorfon, naled, ODM, permethrin, bifenthrin, and baythroid. The latter 3 are pyrethroids. Future studies with synergism, bioassays and enzyme tests upon target lygus bugs will indicate if there are logical patterns of insecticide alternation that might help redress resistance. We plan to expand our range of alternative insecticide tests if funding can be found.

Table 38 provides an example of how IPM or Extension personnel might use these detection methods. An alfalfa seed farm in Malheur County Oregon, was selected and spot

tests were performed periodically in 1987. Esterase levels increased in Lygus hesperus from May 20 to June 26. Immediately after June 26, split plots were treated with 0.375 lb ai/acre of ODM and 1 lb ai/acre trichlorfon. ODM and trichlorfon provided 97.3% and 42.7% control of lygus bugs, respectively. A subsequent spot test on August 21 showed the esterase level further elevated.

All populations of lygus bugs in Malheur County have strong resistance to trichlorfon. This correlates well with recent efficacy data from IPM records which shows trichlorfon of lygus bugs to be less than 0%. As of 1987, no populations of ODM-resistant lygus bugs had been observed in Malheur County though Malheur County has lower proportions of extremely resistant Lygus hesperus (Table 12). Efficacy of ODM remains at more than 90%.

Impact of Resistance upon Effects of Insecticide Cancellations: Redressing resistance has some possibilities for natural cycles of high and low esterase levels in Lygus hesperus and migration into alfalfa seed areas from other host plants can provide at least early "windows" of better efficacy in some alfalfa seed areas. Some alfalfa seed production areas, for example Montana, do not now have resistance problems and maximum effort should be made to retain efficacy. If the presence of resistance in Idaho and Oregon is used to "excuse" or make trivial a decision about registration of these insecticides, it will deprive a viable seed area, as Montana, of effective pest control tools.

The benefits of any bee-safe, lygus bug-controlling insecticide are greatly magnified in the context of resistance to any of the few insecticides which now serve that role. It is not easy to find alternative insecticides because of the ecological and biological requirements, dearth of new insecticidal materials, and status of alfalfa seed as "minor" crop which reduces commercial interest in developing alternatives. The possible suspension of ODM, naled, trichlorfon, or mevinphos would have long term impacts on continued progress toward an insecticide resistance management program for alfalfa seed production.

Section I emphasizes the tremendous value of the alfalfa seed crop as replanting for ca. 25,000,000 acres of alfalfa and alfalfa mixtures for hay. Yet the acreage in the northwest is less than 150,000. Presumably, regions where Lygus hesperus resistance has not yet developed could take on larger roles in alfalfa seed production if resistance itself begins to curtail effective insecticidal control. This will not be possible, however, if the registration process removes the option of insecticides. Lygus hesperus populations reach such high levels on blooming alfalfa that alternative cultural and biological controls are generally ineffective.



Table 37. Examples of bioassay results using glass vials or plastic bags with trichlorfon and adults of Lygus hesperus<sup>a</sup>

Year	Location	N	LC <sub>50</sub> , ug/container <sup>b</sup>		
			Mean	SD	Range
<b>In Vials</b>					
1980	Logan, UT	1	0.7		--
	Delta, UT	8	3.2	3.2	0.1-13.2
	Nampa, ID	6	4.3	2.0	2.8-6.6
1984	Caldwell, ID	15	5.5	3.9	1.7-9.5
<b>In Bags</b>					
1988	Utah	5	6.0	4.9	4-13
	Idaho	2	507.0		277-737
	Oregon	3	187.0	13.0	177-202

<sup>a</sup>Source: W.A. Brindley, B.C. Simko, and others (unpublished).

<sup>b</sup>LC<sub>50</sub> values ≤ 1 ug/vial or 4 ug/bag are characteristic of susceptible populations.

Table 38. Trichlorfon resistance levels as determined by esterase levels in Lygus hesperus populations in a single alfalfa seed field located in Malheur County, Oregon, 1987<sup>a</sup>

Date tested	Esterase and resistance percentage		
	High	Moderate	Low
5/20	14.2	81.0	4.8
6/5	33.3	61.9	4.8
6/18	38.1	61.9	0.0
6/26 <sup>b</sup>	57.1	42.9	0.0
7/21	76.2	19.0	4.8

<sup>a</sup>Source: B.C. Simko and W.A. Brindley (unpublished).

<sup>b</sup>Plots sprayed after spot test with ODM or trichlorfon (see text).

### Oxydemeton-methyl Usage

Survey data from California reveal the insecticides Oxydemeton-methyl, naled, mevinphos and trichlorfon are currently rarely recommended and if used represent a very small percentage of the total pounds of insecticides applied to alfalfa seed. The low current use of these materials relative to the northwest is the result of several factors. 1) The pest complex in the cotton, safflower, alfalfa seed rotation of the South San Joaquin pose much different challenges to past management systems. 2) Populations of lygus bugs have developed significant resistance to older OPs including ODM and trichlorfon. Recently some evidence of lygus resistance to mevinphos has also been observed. 3) In California producers rely almost exclusively on the honey bee to pollinate seed fields. Honey bees differ from leafcutting and

alkali bees in insecticide tolerance and sublethal effects from exposure. This allows the use of a different array of compounds in the California IPM program.

In Fresno and Kings Counties, occasional use of mevinphos does still occur as a pre-harvest treatment after honeybee hives are removed from fields. In Glenn County, a minor seed production area in northern California, ODM use does still occur. Some operators use leafcutting bees along with honey bees for pollination. In 1988 120-180 acres were treated with the 0.5 lb ai rate of ODM.

In the northwest, where the application of these insecticides is still prevalent, use data is reported in Table 39. More than 75% of Oregon's alfalfa seed production is in Malheur County. This extreme eastern county is contiguous with the SW Idaho production area. Production systems and crop rotations are very similar. To simplify data tables the Idaho and Oregon data are combined.

In Washington two distinct production areas exist. The Columbia Basin district and the Gardena-Touchet district have different management and rotation systems. The data from these areas are reported separately.

1988 estimates rank ODM as the most preferred treatment in alfalfa for lygus control with 42,861 lbs ai used in the northwest. Naled was second in amount used at 29,331 lbs ai. ODM represents nearly 50% of all treatments targeted for lygus control during the flowering-pollination period (Table 40).

In most northwest production areas alfalfa seed growers tend to apply insecticides themselves with field sprayers pulled by closed cab tractors. The Columbia Basin district in Washington is the exception with all four insecticides applied by aircraft. This preference for private ground application of treatments stems from strong evidence of better performance of the materials when sprayed 2-3 inches over the canopy with higher volume of spray. Better treatment timing is another advantage particularly when commercial applicators have a backlog of orders. The private applicator often can treat within 12 hours after making a decision based on the latest pest and beneficial counts (Table 41).

Virtually all alfalfa seed growers are trained, certified and licensed applicators. Training is conducted by university Extension personnel while the certification and licensing is administered by state departments of agriculture. In Oregon new private applicator rules have been adopted which will require all alfalfa seed growers to take continual recertification training to maintain a license.

Table 42 provides potential exposure estimates for ODM, Naled, Mevinphos and Trichlorfon in the northwest region. Not all alfalfa seed growers elect to apply their own insecticides so the exposure data would only apply to a subset of the grower population. In situations where private applicators are putting on more than one treatment per season, the interval between treatments is generally two or more weeks. The average alfalfa seed acreage managed by Idaho and Oregon growers is much smaller than for producers in Washington or Nevada. Therefore survey data shows less exposure time is required while mixing, loading and spraying fields for Idaho and Oregon seed producers.

Post treatment exposure to the insecticides is negligible. Reentry periods are observed and very little farmer or farm laborer activity occurs in fields until prior to harvest.

Acute toxicity data for the four insecticides is summarized in Table 43.



Table 39. Pesticide usage patterns on alfalfa during 1988<sup>a</sup>

	% Acreage treated	Application rate (lbs ai/A)	No. applications per season	Total amount used (lbs ai)
<u>Idaho and Oregon</u> : 45,000 acres				
oxydem.-methyl	90	0.375	2.0	30,375
naled	30	0.75	2.0	20,250
mevinphos	10	0.375	2.5	4,219
trichlorfon	5	1.0	1.0	2,250
<u>Washington</u> (Gardena/Touchet Area): 16,000 acres				
oxydem.-methyl	65	0.375	1.0	3,900
naled	30	1.000	1.5	7,200
mevinphos	10	0.375	2.5	4,219
trichlorfon	15	1.000	1.0	2,400
<u>Washington</u> (Columbia Basin Area): 10,000 acres				
oxydem.-methyl	95	0.375	1.5	5,344
naled	2	0.500	1.0	100
mevinphos	25	0.375	1.0	938
trichlorfon	20	1.000	1.0	2,000
<u>Nevada</u> : 9,500 acres				
oxydem.-methyl	60	0.438	1.3	3,242
naled	25	0.750	1.0	1,781
mevinphos	70	0.375	1.5	3,741
trichlorfon	1	1.000	1.0	95
<u>Montana</u> : 18,610 acres (dryland and irrigated)				
oxydem.-methyl	0	0	0	0
naled	0	0	0	0
mevinphos	0	0	0	0
trichlorfon	19	1.000	1.0	3,536

<sup>a</sup>Source: NAPIAP Survey, Fall 1988.

Table 40. Summary of Oxydemeton-methyl, naled, mevinphos and trichlorfon use in key alfalfa seed states<sup>a</sup>

State	Lbs. ai Used in 1988			
	ODM	Naled	Mevinphos	Trichlorfon
Idaho/Oregon	30,375	20,250	4,219	2,250
Washington (Gardena/Touchet)	3,900	7,200	0	2,400
Washington (Columbia Basin)	5,344	100	938	2,000
Nevada	3,242	1,781	3,741	95
Montana	Trace	Trace	Trace	3,536
California	Trace	0	Trace	0
Total	42,861	29,331	8,898	10,281

<sup>a</sup>NAPIAP Survey, Fall 1988

Table 41. Alfalfa pesticide applicator profile and application methods<sup>a</sup>

State	No. growers	Average acreage	% Growers <sup>b</sup> licensed	Air	Percentage acreage treated by:	
					Sprayer	Closed cab tractor
ID/OR	700	64	100	40	60	100
WA-G/T	50	320	100	25	75	95
WA-CB	45	222	100	100	0	0
NV	30	317	100	20	80	100

<sup>a</sup>Source: NAPIAP Survey, Fall 1988.

<sup>b</sup>Licensed as private applicators.



Table 42. Potential exposure estimates for private applicators of alfalfa pesticides\*

Chemical & State	No. hours required to:		No. applications per season	Potential exposure per year (hrs)
	Mix & load	Apply		
<u>Oxydemeton-methyl</u>				
ID/OR	.5-1	2-4	2	5-10
WA-G/T	2-3	5-10	1	7-13
WA-CB	0	0	1	0
NV	2-3	5-10	1	9-17
<u>Naled</u>				
ID/OR	.5-1	2-4	2	5-10
WA-G/T	2-3	5-10	2	10-20
WA-CB	0	0	1	0
NV	2-3	5-10	1	7-13
<u>Mevinphos</u>				
ID/OR	.5-1	2-4	2	6-12
WA-G/T	2-3	5-10	0	0
WA-CB	0	0	1	0
NV	2-3	5-10	2	10-20
<u>Trichlorfon</u>				
ID/Or	.5-1	2-4	1	2-5
WA-G/T	2-3	5-10	1	7-13
WA-CB	0	0	1	0
NV	2-3	5-10	1	7-13

\*Source: NAPIAP Survey, Fall 1988.

Table 43. Acute toxicity of alfalfa pesticides\*

Insecticide	Recommended rate (lbs ai/A)	Toxicity <sup>b</sup> class	LD50 mg/kg	
			Oral (rat)	Dermal (rabbit)
oxydem.-methyl	0.375-0.5	II	65-75	350 (rat)
naled	0.5-1.0	II	530	1,100
mevinphos	0.25-0.5	I	3-12	16-33
trichlorfon	0.75-1.0	II	150-400	>2100

\*Source: Farm Chemicals Handbook, 1988 and PNW Insect Control Handbook, 1988.<sup>b</sup>I = LD<sub>50</sub> less than 49, II = LD<sub>50</sub> 50 to 499.

## Economic and Social Impacts of Oxydemeton-methyl Use

The cost of oxydemeton-methyl, Naled, Mevinphos and Trichlorfon relative to the benefits realized by the alfalfa seed producer are negligible. Timely control of lygus bugs and secondary pest while conserving essential pollinators increases the per acre yield and value of the commodity 5-10 fold. The practices which include the selective use of this group of insecticides are fundamental to the economic survival of the alfalfa seed enterprise in the northwest. Table 44 provides the current prices for the insecticides and the range of treatment costs per acre. The average cost per application would be \$11.32 per acre. In Table 45 this typical treatment cost is compared to other related production inputs. Based on published cost enterprise analysis sheets the cost of a single treatment represents 1.5-2.5% of the total cost of production. Yet a single lygus bug treatment during the flowering period can increase the per acre value of production nearly \$160 (see Table 10). The 1988 average commodity price was \$1.25/lb with average yields around 500 lbs/acre. With a gross per acre income of \$625 a single insecticide treatment would represent only 1.8% of the value of the commodity.

Potential exposure from private application of these four insecticides is compared to the increase in overall farm income in Table 46. Even in the unlikely event a grower would apply all four insecticides once per season he would have increased his farm income from \$800-\$2,000 per hour of application time.

As indicated in Section I, this economic benefit to the alfalfa seed producer is only the first level of benefits. Nearly all the alfalfa seed is sold for replanting of alfalfa hay which supports the nation's dairy, beef, and other animal industries. Pelleted and cubed alfalfa is also a growing export commodity.

Table 44. Cost of insecticide treatment in Northwest United States (\$/Acre)

Insecticide	Cost of Insecticide	Cost of Application	Total cost
oxydem.-methyl	6.50-9.00	4.00-7.50	10.50-16.50
naled	2.90-6.00	4.00-7.50	6.90-13.50
mevinphos	2.75-5.50	4.00-7.50	6.75-13.00
trichlorfon	5.00-7.00	4.00-7.50	9.00-14.50
Range			6.75-16.50
Mean			11.33



Table 45. Cost factors for typical alfalfa seed operation in the Northwest<sup>a</sup>

State	Cost of treatment		Cost of <sup>d</sup> pollination	Total cost	% of total for single trt.
	Insecticide <sup>b</sup>	All pesticides <sup>c</sup>			
	-----\$/Acre-----				
Idaho	11.33	108.00	172.50	533.40	2.1
Oregon	11.33	126.00	150.00	774.20	1.5
Washington (G-T)	11.33	67.72	25.71	602.36	1.9
Nevada	11.33	103.32	75.00	449.26	2.5

<sup>a</sup>Source: cost enterprise budgets published by University of Idaho 1987, Oregon State University 1986, Washington State University 1986 and University of Nevada 1981.

<sup>b</sup>Average NW treatment costs for ODM, Naled, Mevinphos, or Trichlorfon includes application costs.

<sup>c</sup>Includes all insecticide, acaricide and herbicide costs in typical operation.

<sup>d</sup>Washington 75% alkali bee, 25% leafcutting bee; all others 100% leafcutting bee.

Table 46. Comparison of farm income benefits and exposure risks to oxydemeton-methyl, naled, mevinphos, and trichlorfon

State	Average yield w/ treatment (lbs/A)	Average <sup>a</sup> yield w/o treatment (lbs/A)	Yield increase (lbs/A)	Chemical price (\$/lb)	Income increase (\$/A)	Area <sup>b</sup> treated	Total		
							increase in farm income (\$)	Greatest <sup>c</sup> application exposure (hrs/yr)	Income: <sup>d</sup> exposure (\$/hr)
Idaho/Oregon	200	400	200	1.25	250	64	16,000	20	800
Washington (G/T)	200	400	200	1.25	250	320	80,000	39	2051
Nevada	200	400	200	1.25	250	317	79,250	39	2032

<sup>a</sup>Estimate of yield increase from controlling lygus bugs during pollination-flowering period. Does not include factors of yield increase from controlling secondary insect pests and weeds, pollination and irrigation management.

<sup>b</sup>Total acres alfalfa seed/total no. growers.

<sup>c</sup>Worst case exposure: maximum time to mix, load, and spray one time during flowering-pollination period.

<sup>d</sup>Ratio of increased income (\$) to increased potential exposure time (hrs).



## **Methods of Analysis**

Data gleaned for the assessment of oxydemeton-methyl, naled, mevinphos and trichlorfon uses on alfalfa seed came from a full spectrum of sources. University personnel, seed company representatives, chemical dealer representatives, private consultants and growers all contributed estimates, statistics and observations cogent to the objectives of the report. A standardized survey form was used to collect most of the use data.

Survey data from Idaho, Oregon, Washington and Nevada was collected at special industry meetings held in the production areas during the fall of 1988. Attendance to the meetings by knowledgeable industry leaders resulted in excellent discussion and collection of survey estimates. This process of collecting information directly from the users and recommenders of the insecticide lends special credibility to the data. (See list of attendees.)

California and Montana, minor users of the four insecticides, submitted data by mail and phone.

Special thanks to scientists from the states of Oregon, Idaho, Washington, Nevada, Montana and California for their technical assistance.





## OXYDEMETON-METHYL USE ON FIELD CROPS

### Oxydemeton-methyl Use on Sorghum

Z. B. Mayo  
University of Nebraska

Approximately 14.4 million acres of sorghum were harvested in the United States in 1986 (USDA Agr. Stat., 1987). Of this total, approximately 13.9 million acres were grain sorghum. The projected acreage of grain sorghum for 1987 and 1988 was reduced to 10.5 million acres (Delvo et al. 1988). Based on acres planted in 1987, grain sorghum ranked as the 6th most important field crop and the 4th most important row crop in the United States (Table 47). Almost 80 percent (Delvo et al. 1988) of the total grain sorghum acres were located in the states of Kansas (3.7 million acres), Texas (2.5), Nebraska (1.2), and Missouri (0.8).

The most serious insect and mite pests of sorghum in the United States in order of importance are: Western U.S. - greenbugs, Schizaphis graminum (Rondani); mites (Banks grass mite, Oligonychus pratensis (Banks) or two-spotted, Tetranychus spp.); sorghum midge, Contarinia sorghicola (Coquillett); chinch bug, Blissus leucopterus (Say); and corn earworm, Heliothis zea (Boddie); Eastern U.S. - sorghum midge; sorghum webworm, Celama sorghiella (Riley); lesser cornstalk borer, Elasmopalpus lignosellus (Zeller); fall armyworm, Spodoptera frugiperda (J.E. Smith); and corn earworm (Pitre, 1985). The corn leaf aphid, Rhopalosiphum maidis (Fitch) and the yellow sugarcane aphid, Sipha flava (Forbes) are also considered pests in some areas. The estimated annual loss from each of the various pests ranges from 0.5 percent for mites to 4.0 percent for the sorghum midge (Table 48; Wiseman and Morrison 1981). Cultural practices; resistant varieties, and insecticides, or combinations of the above, have been used to control the various pests. Because of the relatively low value per acre of sorghum and the availability of fairly effective cultural controls and resistant varieties for some pests, insecticides have not been used as extensively on sorghum as on some other field crops. In 1988, only 1.6 million lbs. of active ingredient (Table 47) were projected to be applied to grain sorghum in the United States.

Oxydemeton-methyl (ODM) is registered on sorghum for control of greenbug, corn leaf aphid, yellow sugarcane aphid, and backs grass mite. The recommendation for banks grass mite applies only to the Southwest including the states of Kansas, Oklahoma, Texas, Colorado, New Mexico, and Arizona. The greenbug is by far the most wide spread the damaging of these four pests.

Although the greenbug has long been considered a serious pest of small grains in the United States (Wadley 1931), it has only been a pest of grain sorghum since 1968 (Harvey & Hackaerott 1969, Wood 1971). It now occurs throughout the sorghum producing areas of the United States (Teetes 1976). The greenbug has the potential to cause severe damage to sorghum each year. Naturally occurring predators and parasites have not provided consistent control on greenbug susceptible sorghum hybrids. However, the use of greenbug resistant sorghum hybrids, which slows development or reduces greenbug populations, has enabled predators and parasites to be economically effective in reducing greenbug damage in many instances. Wiseman and Morrison (1981) ranked resistant sorghum hybrids as the most important means of reducing greenbug damage reduction method, behind predators and parasites (Table 49). Even with these population and damage modifying mechanisms, the greenbug is still listed as the second most damaging pest of sorghum (Table 49).

As long as resistant hybrids are available, devastating losses can be avoided most years and insecticide use should remaining fairly low. However, greenbugs have demonstrated a propensity to develop new biotypes at an alarming rate. Wood (1961) identified a new biotype (B) damaging wheat in 1958. The first greenbug biotype (C) capable of damaging sorghum was

reported in 1968 (Harvey & Hackaerott 1969, Wood et al.). An insecticide resistant biotype (D) was reported in 1974 (Teetes et al. 1975, Peters et al. 1975) and the second sorghum damaging biotype (E) was reported damaging sorghum hybrids possessing resistant to biotype C (Porter et al. 1982). Additional biotypes have been reported damaging other crops (Ratcliffe & Murray 1983). If new biotypes develop that are capable of damaging our biotype C and E resistant sorghum hybrids, increased reliance on insecticides should be expected. This is illustrated by the fact that prior to the development of the sorghum damaging biotype (C), only 2% of the sorghum acreage in the United States was treated with an insecticide in 1966. By 1971, which was after the appearance of biotype C greenbugs and before the release and wide spread use of greenbug resistant hybrids, the percent treated acres increased to 39% (Andrilenas 1975). Most of this increase can be attributed to the greenbug (Starks & Mayo 1985). By 1976, after the introduction of greenbug resistant sorghum hybrids, the percent insecticide treated sorghum acres decreased to 27% (Eichers et al. 1978). The wide spread use of greenbug resistant sorghum hybrids is estimated to have reduced the use of insecticides for greenbug control by approximately 50%.

The Banks grass mite along with the two-spotted spider mite are considered to be the second most serious arthropod pest of sorghum in the western United States (Pitre 1985). Although predators are important population limiting factors, miticides are considered to be the only method to reduce populations once they start to increase (Ehler 1974, Wiseman & Morrison 1981).

Both the Banks grass mite and the two-spotted spider mite have shown the ability to develop resistance to a variety of insecticides and miticides (Ward & Tan 1977). Insecticide application to control greenbugs in sorghum have compounded Banks grass mite problems by killing predators and selecting for miticide resistance (Young & Teetes 1977). In some areas the Banks grass mite was considered a secondary pest until greenbug insecticide treatments became common (Young & Teetes 1977).

The corn leaf aphid is not generally considered an economic pest of sorghum and insecticides are seldom recommended (Wilde & Ohiagu 1976). The yellow sugarcane aphid can be a devastating pest in some areas. Usually it is only a problem in the Gulf Coast states but occasionally damages sorghum as far north as Kansas (Starks & Mirkes 1979). Insecticides are the primary means of controlling the pest.

### **Oxydemeton-methyl Usage and Alternative Chemicals**

The pests of sorghum that oxydemeton methyl is registered to control are primarily problems in the western sorghum producing states. Therefore, insecticides use questionnaires were mailed to the 12 states west of the Mississippi a river that were listed as sorghum producing states in the 1987 USDA Agricultural Statistics report. Of the nine states that responded to the questionnaire, five indicated no known use the Kansas reported only very minor use of oxydemeton methyl on sorghum (Table 50). Texas reported the highest use with six percent of the insecticide treated acres treated with oxydemeton methyl. Nebraska reported oxydemeton methyl use on one percent of the treated acres. Texas listed four alternative insecticides, Nebraska listed six, Kansas three, and Louisiana one (Table 50). Only one pesticide application per year was indicated for oxydemeton methyl or the alternative insecticides. The alternative insecticides were generally considered to be equally effective as oxydemeton methyl. However, the cost of oxydemeton methyl was 45-55% greater than the alternatives (Table 50).

Price appears to be the major factor limiting the use of oxydemeton methyl on sorghum. Entomologists in both Texas and Oklahoma indicated that oxydemeton methyl could be an important sorghum insect and mite control agent if pesticide resistance occurs, alternative insecticides are banned, or if oxydemeton methyl becomes cost competitive in the future.



Based on the small percentage of acres treated with oxydemeton methyl and the number of equally effective and cheaper alternative pesticides, cancellation oxydemeton methyl for use on sorghum would have minimal immediate effects on sorghum production in the United States.

Table 47. 1988 acreage and insecticide use on field crops in the United States\*

Crop	No. acres planted	-----Insecticide use-----	
		Total amt. (million lbs/AI)	Rate (AI/acre)
corn	67.5	24.8	0.37
wheat	65.9	1.9	0.03
soybeans	58.5	9.0	0.15
barley & oats	23.7	0.2	0.01
cotton	12.2	18.0	1.48
grain sorghum	10.4	1.6	0.15
rice	2.9	0.5	0.17
peanuts	1.7	1.3	0.76
tobacco	0.6	2.4	4.00

\*Source: Delvo et al., 1988

Table 48. Estimated grain sorghum yield loss to the major insect and mite pests of sorghum in the United States\*

Pest	% Yield loss
sorghum midge	4.0
greenbug	2.5
fall armyworm and corn earworm	1.5
sorghum webworm	0.5
mites	0.5
Total	9.0

\*Source: Wiseman & Morrison, 1981



Table 49. Principal methods of controlling major insect and mite pests of grain sorghum, ranked in order of importance for each pest<sup>ab</sup>

	Insecticides	-----Control method-----		
		Cultural practices	Resistant varieties	Predators & parasites
sorghum midge	2	1	na <sup>c</sup>	na
greenbug	3	4	1	2
fall armyworm and corn earworm	3	1	na	2
sorghum webworm	2	1	na	-
mite	1	na	na	2

<sup>a</sup>Source: Wiseman & Morrison, 1981.

<sup>b</sup>Ranked in order of decreasing importance (1 = best control method).

<sup>c</sup>Not applicable: control method not available.

Table 50. Use of oxydemeton methyl (ODM) and alternative insecticides on sorghum in the United States

State	All pesticides		oxydemeton-methyl		Alternative chemicals	
	No. acres planted (millions)	% <sup>a</sup> acres treated	% <sup>b</sup> acres treated	Cost/ <sup>c</sup> acre	Chemical name	Cost/acre
Kansas	3.70	11	0		ETH DIM MET	
Texas	2.30	65	6	9.30	CHL	5.66
					ETH	4.13
					DIM	5.40
					MAL	5.63
Nebraska	1.50	18	1	13.76	ETH	6.40
					MAL	7.82
					DIS	7.32
					DIM	7.72
					CHL	6.26
					CAR	7.38
Oklahoma	0.55	0				
Missouri	0.45	0				
Arkansas	0.40	0				
S. Dakota	0.31	0				
Colorado	0.30	0				
Louisiana	0.12		0		DIM	4.00

<sup>a</sup>All reports that listed number of applications, indicated only one application of oxydemeton methyl or any of the other pesticides per year.

<sup>b</sup>This column represents the percent of the insecticide treated acres that were treated with oxydemeton methyl.

<sup>c</sup>Costs include application costs.

<sup>d</sup>ETH = ethyl parathion, DIM = dimethoate, MET = methidathion, CHL = chlorpyrifos, MAL = malathion, DIS = disulfoton, CAR = carbofuran.



## **Oxydemeton-methyl Use on Sugarbeets**

Z. B. Mayo  
University of Nebraska

In 1986, approximately 1.2 million acres of sugarbeets were planted in the United States (USDA Agr. Stat., 1987). The states that included acres planted on their questionnaire responses, indicated there was approximately a 12 percent decrease in acres planted to sugarbeets from 1986 to 1988 (Table 1). There are no recent estimates of acres of sugarbeets treated with insecticide. However, Andrienas (1975) indicated that approximately 30 percent of the sugarbeet acreage was treated with insecticide in 1971 which was an increase from 112 percent in 1966.

Oxydemeton-methyl is registered on sugarbeets for control of aphids, leafhoppers, and mites. In Mobay Corporation's July 15, 1988, report to the oxydemeton methyl assessment team, they indicated that of the total acres (all crops) treated with oxydemeton methyl in the United States, 3.4 percent of the acres was sugarbeets. The report also indicated that oxydemeton methyl was used on sugarbeets in the states of California and Oregon.

Questionnaires were sent to extension entomologist in 11 of the 12 states (Mississippi was not surveyed) listed as producers of soybeans in the 1987 USDA Agr. Stat. Rpt. Responses were received from all states except California. Idaho indicated oxydemeton methyl may be used on a few acres during bean aphid outbreak years and Nebraska indicated that it was used on less than one percent of the treated acres (Table 51). No oxydemeton methyl use was reported from the other states. Effective and cheaper alternative insecticides were reported by some states. Oxydemeton-methyl was not reported to be more efficacious than the cheaper alternatives.

At present, oxydemeton methyl does not play an important role in the production of sugarbeets in the United States. Price appears to be the major factor limiting its use on sugarbeets. Based on the small number of treated acres and the availability of cheaper, effective alternative insecticides, cancellation of oxydemeton methyl for use on sugarbeets would have minimal immediate effects on sugarbeet production in the United States.



Table 51. Use of oxydemeton methyl (ODM) and alternative insecticides on sugarbeets in the United States

State	All pesticides		oxydemeton-methyl		Alternative chemicals	
	No. acres planted (thousands)	% Acres treated	% <sup>c</sup> acres treated	Cost/ <sup>d</sup> acre	Chemical <sup>e</sup> name	Cost/ acre
Minnesota	250		0			
California	192 <sup>a</sup>		*			
North Dakota	165 <sup>a</sup>		0			
Idaho	150	25 <sup>b</sup>	0		DIS	
Mississippi	137 <sup>a</sup>		*			
Nebraska	63		0	9.75	DIS	5.67
					MAL	3.71
					PAR	1.20
Wyoming	50		0		PHO	
					ALD	
Montana	45		0		CAR	4.00
					DIA	2.50
					DIB	11.68
					PAR	1.41
					MAL	2.75
					NUD	8.00
					ALD	3.50
					PHO	1.50
Colorado	38 <sup>a</sup>		0			
Texas	35		0			
Ohio	17		0			
Oregon	13 <sup>a</sup>		0			

<sup>a</sup>Source: USDA Agr. Stat. Rpt., 1987. All other acres planted data from the NAPIAP questionnaires returned by the states.

<sup>b</sup>Idaho indicated that 25-30% of the acres were treated in outbreak years.

<sup>c</sup>Colorado reported no significant use, Nebraska reported less than one percent of the treated acres were treated with ODM, and Idaho indicated very limited ODM use in bean aphid outbreak years.

<sup>e</sup>ETH = ethyl parathion, MAL = malathion, DIS = disulfoton, PHO = phorate, ALD = aldecarb, CAR = carbaryl, DIA = diazinon, DIB = dibrom, NUD = nudrin, ALD = aldecarb.

<sup>d</sup>Report not received from this state.

## Oxydemeton-methyl Use on Mint

Craig R. Baird  
University of Idaho

Peppermint (Mentha piperita) and spearmint (M. spicata) are perennial crops grown for production of oils used in flavoring various products. Classified as "essential oils" because of the strong essence produced, these oils are complex organic oils composed of various terpenes which may vary markedly in composition and quality (Landing, 1969).

Production of mint oil in the United States is a specialized effort requiring cooperation between growers, research and extension personnel, agricultural chemical dealers, oil processors, oil testers, and end users. The mint grower must manage his crop with three main components in mind: (1) Irrigation management, (2) Pest management (insects, diseases, weeds, nematodes), and (3) Proper harvest timing. Neglect of any component results in lowered yield and/or reduced quality of mint oil (Green, 1963).

The mint oil industry produces peppermint and spearmint oils as its major products. These essential oils are taste-tested and blended to produce more desirable qualities before being sold to end users for use in flavoring chewing gum, candy, foods, and toothpaste, etc. A very small acreage of other types of mint, such as citrata (M. citrata), produces an essential oil used as a fragrance in scenting soaps, toiletry products, etc.

Mint production is centered in two main areas of the United States -- the Pacific Northwest (Oregon, Idaho, Washington, Montana), and the Midwest (Indiana, Michigan, Wisconsin). Climatic and soil differences result in quite different production practices, oil yield, oil quality, and overall crop management. For example, peppermint oil produced in the Midwest is preferred because it is lower in menthofuran than western oil, but the midwestern yield per acre is only 30 to 50% that of the western states.

Dollar value of the mint oil industry has continued to increase during the 1980's and is projected to continue increasing during the 1990's because of increasing demand and acreages and slightly increasing yields. Pest management difficulties from loss of herbicide and insecticide tools may reduce yields and quality, and thereby contribute to higher prices paid for available oil and subsequently higher prices for mint-flavored products for the consumer (Tables 52-55).

### Pest Management

The major insect pests of mint in the United States include the mint root borer (Fumibotys fumalis), mint flea beetle (Longitarsus waterhousei), mint aphid (Ovatus crataegarius), two-spotted mite (Tetranychus urticae), cutworms (Euxoa spp.), alfalfa looper (Autographa californica), and strawberry root weevil (Otiorhynchus ovatus) (Berry, 1977; Calkin & Fisher, 1982; Hollingsworth et al, 1984; Baird & Homan, 1986; Fisher et al, 1988; Pike et al, 1988)

Important weed pests include lambsquarter (Chenopodium album), nettles (Urtica spp.), pigweed (Amaranthus retroflexus), smartweed (Polygonum persicaria), goldenrod (Solidago canadensis), and maretail (Conyza canadensis) (Green, 1963).

Several plant diseases affect mint and are important concerns to growers (Maloy & Skotland, 1969). These include verticillium wilt (Verticillium albo-atrum var. menthae), powdery mildew (Erysiphe cichoracearum), and mint rust (Puccinia menthae). Nematodes of importance to mint production include the root knot nematode (Meloidogyne hapla) and the root lesion nematode (Pratylenchus minyus).



Although an in-depth integrated pest management (IPM) system has never been embraced by the mint industry as a whole, most growers utilize various aspects of IPM in their pest control planning. Many growers produce other crops for which IPM practices are well developed and many practices such as pest monitoring, economic thresholds, biological control, and useful cultural practices carry over into mint oil production. Entomologists at Oregon State University have developed effective IPM programs for mint insects in that state but few of the other mint producing states have followed suit. Most growers nationwide, therefore, still rely on traditional chemical control methods for insect pests.

Mint growers on average are a well educated group and maintain a high level of current knowledge. They must do so to remain competitive. Nearly 100 percent hold private applicator certification and attend two to three seminars or meetings per year to maintain currency.

The success of effective pest control on mint is in serious jeopardy because of the lack of new pesticide registrations and the threatened loss of existing products to the re-registration process. Mint's status as a minor crop seriously limits mint growers' ability to receive new pesticide registrations or even serious consideration for such by the pesticide companies. In most cases, agricultural chemical companies are unwilling to invest research dollars into minor use crops such as mint. Often they are unwilling to allow their products to be tested or considered for registration on mint even at no cost to themselves. Chemical companies feel that the relatively small mint acreage in the U.S. does not justify the effort and expense demanded by the ridiculous and cumbersome registration process.

Mint does not require insect pollination. Nevertheless, various bees visit the crop for nectar and pollen when it is blooming. In the Pacific Northwest, honey bees (Apis mellifera), alfalfa leafcutting bees (Megachile rotundata), and alkali bees (Nomia melanderi) are placed in alfalfa seed fields and frequently these are near, even adjacent to mint fields. All three bee species are affected adversely by harsh insecticides applied to mint. Oxydemeton-methyl is the least toxic to bees of all insecticides applied to mint and is a much safer alternative when used on mint near alfalfa grown for seed (Johansen et al,1974; Johansen,1982; Homan & Baird,1987).

### **Oxydemeton-methyl Usage**

Oxydemeton-methyl (ODM) is registered and used on mint crops for controlling mint aphids and two spotted mites (Table 56.). ODM labeled rate for these pests is 3 pints of Metasystox-R spray concentrate (.75 lb ai) per acre applied as a foliar spray with ground equipment. There is a 14 day preharvest interval (PHI) (Baird & Homan,1986; Fisher et al, 1988).

In Idaho, Washington, and Michigan, ODM is used to control mint aphids. If populations of this pest reach 30 per sweep prior to harvest, plant wilting and loss of vigor may occur resulting in yield loss of 20 to 40 percent. In some cases, the mint plants die, causing permanent loss of stand. ODM is the primary aphicide used in mint with acephate, methomyl, and malathion as alternative choices. Acephate and methomyl are more expensive for similar pest efficacy and are more hazardous to pollinators in nearby fields. Malathion is less expensive but is less effective in controlling aphids and more hazardous to pollinators.

In Oregon and Indiana, ODM is used as a miticide to control two-spotted mites. Mites cause drying of leaf tissue and subsequent loss of oil. Heavy populations, if left uncontrolled, severely reduce vigor and cause plant mortality and loss of stand. Weed competition is frequently aggravated in damaged, thin stands. ODM is not the first choice of miticide in any of the states but is an important alternative. Wisconsin and Montana mint growers have only minor mite problems and use relatively little ODM, preferring Kelthane or Omite where available. Malathion is used to suppress mites by some growers in Wisconsin.



## **Annual Use Patterns**

Survey data from the Pacific Northwest reveal oxydemeton-methyl use on 5 to 30 percent of the mint acreage during 1987 and 1988 growing season. ODM treated acreage received one application, occasionally two, per season in most cases (Table 57). From 1 to 20 percent of midwestern acreage was treated with ODM with one application being the general rule. The 1988 growing season was more severe in controlling mites and aphids and required more ODM use than 1987 in most states surveyed.

Most (90%) ODM applications are made by the growers themselves using ground spraying equipment pulled by closed cab tractors. Commercial applicators using similar closed cab ground equipment are utilized for 6% of ODM applications and commercial aerial applicators account for 4% of ODM use. Most growers prefer ground application because of better efficacy and because of immediate availability when pest control is needed.

Most mint growers are certified private applicators and most farmhands working with mixing, loading, and spraying equipment have also attended the private applicator training. Training for applicators has been on-going since 1976-77. Safety and proper protective equipment are stressed in all sessions. Many growers require this training for their farm employees.

Few, if any, growers or mixers/loaders are exposed to more than one application per season (Table 58), and even then exposure is minimized by closed cab tractors and individual protective equipment. Most growers in Pacific Northwest manage mint acreages of less than 100 acres each further reducing exposure during mixing, loading, or application.

Post-treatment exposure is practically non-existent since the grower has no reason to re-enter the field. There are no manual or machine cultural practices required except for irrigation which is controlled from field margins. Growers or farm hands do not normally enter a mint field for cultivation or weed control during the growing season.

## **Summary**

Oxydemeton-methyl is an important and needed insecticide product for most mint producers in the United States. Where it is used, ODM results in higher mint production and higher quality oil. The average grower in the Pacific Northwest utilizing ODM is exposed (using closed cab and protective equipment) to only 4 to 8 hours of ODM use per year in a trade off for gaining several hundred dollars per acre increased quality and production. In addition, ODM is safer on pollinators from adjacent fields and beneficial insects aiding in natural pest control than some of the alternative insecticides.

## **Acknowledgements**

Data and information for assessing ODM use and benefits came from a variety of sources within the mint industry. University personnel from the states of Idaho, Oregon, Washington, Montana, Wisconsin, Indiana and Michigan, farm chemical dealers, mint processor fieldmen, and growers all provided input. A standardized survey form was used to collect data. Telephone follow-up calls were made to many respondents and non-respondents. Some data were gathered at industry meetings held during the fall and winter 1988-89. Key growers from several states were contacted for additional information.

Table 52. Peppermint oil production in United States 1980-86\*

Year	Acreage x 1000	Oil Production X 1000 lbs	Value \$Million
1980	81.3	4,611	43.4
1981	69.5	4,191	39.4
1982	60.9	3,668	33.9
1983	61.3	3,867	39.2
1984	67.2	4,334	47.0
1985	65.1	4,317	44.0
1986	64.2	4,328	46.0

\*Source: National Agricultural Statistics Service

Table 53. Spearmint oil production in United States 1980-86\*

Year	Acreage x 1000	Oil Production X 1000 lbs	Value \$Million
1980	31.3	2,139	20.6
1981	29.2	2,177	20.5
1982	22.8	1,355	17.1
1983	26.2	1,596	19.7
1984	27.9	2,019	25.4
1985	30.1	2,317	27.1
1986	28.5	2,658	28.4

\*Source: National Agricultural Statistics Service

Table 54. Mint oil production by state, 1984-1986\*

	Production 1000 lbs			Value \$Million		
	1984	1985	1986	1985	1985	1986
<u>Peppermint</u>						
Idaho	396	442	584	3.9	4.1	5.1
Indiana	288	182	228	2.9	2.1	3.0
Oregon	2310	2380	2345	26.1	26.2	27.4
Washington	1042	1148	970	10.5	9.5	7.7
Wisconsin	298	165	201	3.6	2.1	2.7
TOTAL	4334	4317	4328	47.0	44.0	46.0
<u>Spearmint</u>						
Idaho	170	187	252	2.4	2.6	3.5
Indiana	156	107	140	2.2	1.4	1.5
Michigan	125	92	87	1.7	1.1	1.0
Oregon	112	154	153	1.6	2.1	2.1
Washington	1254	1605	1859	14.7	17.3	17.9
Wisconsin	202	172	167	2.8	2.4	2.3
TOTAL	2019	2317	2658	25.4	27.1	28.4

\*Source: National Agricultural Statistics Service

Table 55. Mint acreage and production in 1987\*

	Acres harvested	Mean yield/acre (lbs)
Idaho	9.5	80
Indiana	14.0	40
Michigan	5.4	30
Montana	1.7	53
Oregon	35.0	68
Washington	23.9	105
Wisconsin	3.6	38
Total U.S.	92.2	--

\*Source: NAPIAP Survey, June-December, 1988



Table 56. Oxydemeton-methyl and alternative aphicides/miticides on mint<sup>a</sup>

Chemical name	Avg cost per trt	Efficacy <sup>b</sup> on aphids	Efficacy <sup>b</sup> on mites	Safety to <sup>c</sup> pollinators	Safety to <sup>d</sup> beneficials
oxydem.-methyl	9.00	+++	++	++	++
acephate	14.75	+++	na <sup>e</sup>	--	-
methomyl	13.07	++	na	--	--
malathion	3.04	+	-	--	++
propargite	18.00	na	++	+++	+++
kelthane	7.50	na	++	++	+

<sup>a</sup>Source: NAPIAP Survey, Fall 1988<sup>b</sup>Level of control: +++ = excellent; ++ = good; + = fair; - = none<sup>c</sup>Pollinator Safety: ++ = good (10% + mortality); + = marginal (30 % to 50% mortality); -- = poor (80% to 100% mortality)<sup>d</sup>Mortality to beneficial insects: ++ = 10% to 20%; + = 30%; - = 40% to 50%; -- = 60% to 100%<sup>e</sup>na = not applicable: chemical not used on this pestTable 57. Oxydemeton-methyl use pattern by state<sup>a</sup>

	No. acres treated	% treated	Trt. rate lbs ai/A	No. of applications	Usage/season lbs ai/A
<b>Idaho</b>					
1987	9,100	10	.75	1	682.5
1988	11,200	30	.75	1.5	3,780.0
<b>Indiana</b>					
1987	14,100	10	.75	1	1,586.3
1988	12,200	20	.75	1.5	2,745.0
<b>Michigan</b>					
1987	5,400	5	.75	1	202.5
1988	5,200	5	.75	1	195.0
<b>Montana</b>					
1987	1,500	3	.75	1	33.8
1988	1,700	2	.75	1	25.5
<b>Oregon</b>					
1987	31,000	25	.75	1	5,812.5
1988	35,000	30	.75	1.5	11,812.5
<b>Washington</b>					
1987	19,900	5	.75	1	746.3
1988	23,900	10	.75	1	1,792.5
<b>Wisconsin</b>					
1987	9,000	1	.75	1	67.5
1988	10,200	2	.75	1	153.0

<sup>a</sup>Source: NAPIAP Survey, Fall 1988

Table 58. Potential exposure estimates for private applicators using oxdemeton-methyl in mint<sup>a</sup>

	<u>Hours per treatment</u>		Number of treatments per season	Total hours potential exposure/yr
	Mixing & loading	Applying		
Idaho	.5-1.0	4	1.25	7.5
Oregon	1	8	1.0	8.0
Washington	.5	2	1.0	1.0

<sup>a</sup>Source: NAPIAP Survey, Fall 1988





## **Oxdemeton-methyl Use on Cotton**

Lewis Waters  
United States Department of the Interior  
Bureau of Land Management

Oxdemeton-methyl (ODM) is registered to control aphids, mites, thrips, leafhoppers and Lygus (plant bugs) on cotton. The efficiency of controlling insect and mite pests influences how cotton is produced in many areas of the United States. Growers in 17 producing States rely heavily on chemical and non-chemical controls to reduce the damage caused by these pests to cotton. The value to the farm from this crop was \$4.5 billion in 1987.

Information on current cotton insect and mite management practices was obtained from experts who participated in this assessment. Experts estimated the share of harvested acreage treated practices, pesticide materials, or non-chemical methods for important pests in their area for which ODM is registered. Additionally, those estimates include percentage use, dosage per acre, number of treatments likely to occur per annum, and application method.

Expert estimates are often used when current survey or experimental data cannot be obtained with available resources. However, there are always concerns and limitations expressed about the accuracy of expert opinion. Cotton extension and research entomologists have considerable experience in estimating average pest infestations, yield losses, and control practices.

Cotton production is limited to 17 States commercially. These states are Alabama, Arizona, Arkansas, California, Florida, Georgia, Kansas Louisiana, Mississippi, Missouri, New Mexico, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia, for upland cotton, production in Virginia and Kansas is very low for upland cotton. American-Pima cotton is also produced in 4 of the above states, Arizona, California, New Mexico, and Texas.

The following (table 59) displays the distribution of cotton acreage grown in the U.S. in the year of 1987 that have been harvested.

Table 59. United States cotton production in 1987

State	Acres harvested (in thousands)		Yield (lbs/A)	
	Upland	Pima	Upland	Pima
Alabama	333	---	572	--
Arizona	289	90.8	1410	1126
Arkansas	550	---	786	--
California	1140	0.9	1259	1173
Florida	29	--	646	--
Georgia	245	--	662	--
Kansas	9	--	480	--
Louisiana	600	--	782	--
Mississippi	1010	--	829	--
Missouri	189	--	838	--
New Mexico	62	13.9	689	642
North Carolina	95	--	495	--
Oklahoma	400	--	415	--
South Carolina	119	--	428	--
Tennessee	435	--	700	--
Texas	4400	31.0	506	787
Virginia	1	--	373	--
Total	9906	136.6	11870	3728

### Oxydemeton-methyl Usage

As reported in Agriculture Economic Report (AER) No. 599, "Comparisons of State estimates show no significant differences in the acreage treated for Alabama, Arizona, Georgia, Louisiana, Mississippi and South Carolina where chemical controls are used on most of the area planted to cotton. However, expert estimates of acreage treated for Arkansas, California, Missouri, New Mexico, Oklahoma, Tennessee, and Texas were considerably higher than farm survey estimates." In abstracting information from this publication, we can define the share of acreage treated overall and number of applications applied against the labeled cotton pests for ODM as shown in Table 60.

Table 60. Oxydemeton-methyl usage in all states from 1981 to 1984<sup>a</sup>

Target pest	% Acres treated	No. applications
plant bugs, cotton leafhoppers, lygus bugs	37.1	1.37
spider Mites	17.0	1.41
aphids	11.0	1.36

<sup>a</sup>Source: AER #599

Estimated ODM usage is illustrated by State in Table 61.

Table 61. Oxdemeton-methyl usage on cotton in 1987

State	No. acres treated
Alabama	66,600
Arizona	1,000
Arkansas	--
California	14,760
Florida	--
Georgia	61,250
Kansas	0
Louisiana	12,000
Mississippi	101,000
Missouri	0
New Mexico	0
North Carolin	0
Oklahoma	1,000
South Carolina	0
Tennessee	0
Texas	30,000
Virginia	0
Total	287,610

### Alternative Chemicals

A good number of alternative compounds exist for control of the above mentioned cotton pests. Although the price varies considerably from area to area (\$2.50-5.00/Acre) for ODM, this compares favorably with the price of the alternatives and with the efficacy. The questionnaires returned indicate wide acceptance of dicrotophos, dimethoate, parathion, phosphamidon, and endosulfan all ranging in the \$5 to \$6.00 per acre per treatment range. The availability of these alternatives seem to increase their use. However, in 1988, particularly in the States of Georgia and Alabama, insect resistance has developed and ODM is the most likely alternative due to cost, efficacy and residual activity. In fact, resistance is predicted to spread in 1989 and ODM use is expected to increase significantly. Should this resistance develop across the cotton belt only befenthrin would be available at a prohibitive cost of \$13. per acre, and endosulfan which some experts would hold in reserve in case Heliothis spp develops resistance to the pyrethrins.

Most states indicate both ground and aerial applications are made. Although only one State provided an estimate of the percentage done by each method, discussions lead us to surmise that 40-50% of the pesticides applied to cotton are applied aerially and this would include the use of ODM.

### Summary

The loss of oxdemeton-methyl as an alternative where resistance has developed in aphids, mites, and leafhoppers would remove one of the few cost effective alternatives available to the cotton states, and would remove a valuable tool in the development of IPM programs. Of the highly productive cotton states, only California finds that aphids are not a major problem.





## OXYDEMETON-METHYL USE ON ORNAMENTAL TREES AND SHRUBS

James E. Appleby  
University of Illinois

Oxydemeton-methyl is labeled for use on shade and nursery trees and shrubs for control of aphids, European elm scale, elm leaf beetle, mites, and leaf miners. Soil injection of ODM is the only labeled method of application, and its usage is limited to outdoor growing trees and shrubs. Previous to the current label, ODM was registered for use as a foliar spray to control a wide range of insect and mite pests of greenhouse and outdoor ornamental plants.

The Journal of Economic Entomology was searched from 1978 to 1988, and Insecticide and Acaricide Tests from 1980 to 1985 for reports of ODM usage on ornamental plants. The results are summarized in Table 3.

The review indicates that ODM was particularly effective as a foliar spray in controlling certain scales. The alternate chemicals that were more, or as effective, as ODM in controlling scales were foliar sprays of bendiocarb, methidathion, methomyl, azinphos-methyl, oxamyl, and dimethoate. Of these chemicals only dimethoate has an oral LD<sub>50</sub> that is higher than ODM.

Oxydemeton-methyl foliar sprays have been useful in the control of aphids. Insecticides that could serve as alternates include permethrin, oxamyl, and chlorpyrifos. More recently acephate has been used to control aphids.

Mealybugs are serious pests of many indoor plants. Previous research indicates that ODM controlled mealybugs, but that acephate, ethion, or aldicarb may be alternates that would be equally effective.

Oxydemeton-methyl foliar sprays were effective in controlling such pests as whiteflies, bagworms, lacebugs, midges, and mites, but there are several alternate insecticides as listed in Table 3 that could be used as substitutes for ODM.

### **Pesticide Application Methods**

The rate of application is 1 to 1.5 fl. oz. of ODM-2 per inch of tree trunk diameter. The rate for a shrub which is often multi-stemmed is determined by estimating the total diameter of the individual shrub stems at the soil level. The determined dosage is then diluted with an equal or greater volume of water, and the resulting mixture is applied to the plant with equipment capable of injecting the mixture 6 inches or more below the soil surface. It is recommended that 2X as many probe insertions be made as there are inches of trunk diameter at breast height (DBH). An application to non-containerized plant is made around the general area of the drip line.

### **Oxydemeton-methyl Usage**

A questionnaire was sent to extension personnel, nurserymen, and arborists in various states that are known for their leading positions in the production of ornamental plants. The questionnaire was subdivided into two sections. The first section contained questions regarding the usage of ODM on landscape plants. The recipient, if an extension agent, was requested to provide information on the estimated total acreage of landscape plants within the state, if an arborist, the acreage serviced, and if a grower, the landscape plants within the property. Other questions pertained to the average estimated percent of acreage treated with ODM for the past 5 years, method of application, number of applications per year, pests controlled, and if ODM is no longer available what alternate pesticides would be used, and how many times would they

be applied per year. The second section of the questionnaire pertained to the usage of OSM on nursery produced ornamental plants. The same questions were asked as in the first section.

Survey results - Section 1 (Table 1. - Landscapes) - It became quite clear after the survey was completed that a limited amount of ODM has been used on plants in established landscapes during the past 5 years. Several states reported no usage of ODM (FL, IL, TN). Some states or growers reported that ODM was applied as a foliar spray. This is no longer a registered usage, however the survey questionnaire requested information on ODM usage for the past 5 years, so foliar spray applications data has been included. Although several other pesticides are listed as alternate pesticides, several of them are also under special review and may no longer be available. Acephate may be the exception, but this insecticide would be applied as a foliar spray and the problems of chemical drift and the killing of non-target organisms in the urban environment when foliar sprays are applied, limits the usage of such materials.

Section 2 (Table 2 - Nursery crops) - Of the states or growers reporting ODM usage for the past 5 years, only Tennessee reported ODM being used as a soil injection. Several states reported no usage of ODM (AL, FL, IL, OH, MS, VT). The alternative pesticides listed, with the exception of disulfoton and oxamyl, are all applied as foliar sprays. Since the method of soil injection is often not a practical method in nurseries where tremendous variations exist in tree and shrub sizes, foliar sprays are more commonly used.

### **Alternative Chemicals**

From the information provided in the literature review and the survey it appears that foliar sprays of the following alternate chemicals could be used to control the indicated pests: acephate, hendiocarb, thiodicarb, oxamyl, and aldicarb (soil application) - scales; acephate, dimethoate, fluvalinate, permethrin, methyl parathion (encapsulated), oxamyl, and chlorpyrifos - aphids; acephate, dimethoate, methoxychlor, and malathion - whiteflies; acephate, ethion, and aldicarb (soil application) - mealybugs; acephate, chlorpyrifos, carbaryl, and oxamyl (soil application) - leafminers; dicofol, dimethoate, and ethion - mites.

### **Summary**

Previous to the present registration ODM was widely used as a foliar spray on ornamental plants in greenhouses and outdoors, but since its use is now limited as a soil injection and only on outdoor plants, its usage is now minimal. If the ODM present registration were cancelled on ornamental plants, there would probably be little effect on pest management practices in the ornamental plant industry. Presently the ornamental plant industry is under extreme pressure to reduce the use of foliar sprays because of problems associated with chemical drift, and the non-selective killing action associated with the application of many pesticides applied as foliar sprays. It would seem prudent to retain the present registration and encourage more research to investigate techniques using ODM as a soil or trunk injection, and thereby reduce the problems associated with foliar sprays.



Table 62. Oxydemeton-methyl usage on landscape plants<sup>a</sup>

State	Area planted (A)	Area treated (%)	Application <sup>b</sup> method	No. treatments /yr	Pest	Alternative pesticides	No. treatments/yr w/ alternative
Arkansas	na <sup>c</sup>	5	FS	2	scales	acephate	3
Indiana	200	20	FS	3	aphids leafrollers caterpillars plant bugs mites	acephate chlorpyrifos fluvalinate	4 3
New York	1312000	8	SI	1	scales aphids mites leafminers	disulfoton dimethoate demeton	
Rhode Island	na	<1	SI	2	scales aphids mites thrips	aldicarb acephate endosulfan	2 2
Vermont	15000	<5	SI	1	birch leaf- miner		

<sup>a</sup>No usage reported by Florida, Illinois, and Tennessee.<sup>b</sup>FS = foliar spray, SI = soil injection.<sup>c</sup>Not available; information not provided by respondent.

Table 63. Oxydemeton-methyl usage on nursery plants<sup>a</sup>

State	Area <sup>b</sup> planted (A)	Area treated (%)	Application <sup>c</sup> method	treatments /yr	Pest	Alternative pesticides	treatments/yr w/ alternative
Arkansas	25000 ft <sup>2</sup>	5	FS	2	scales	acephate	3
Arkansas	na <sup>d</sup>	10	FS	3	scales	acephate	3
New Hampshire	na	<1	FS	U	leafminer	oxamyl (gm) carbaryl	
New York	3789000 ft <sup>2</sup>	<1	na	2	aphids mites	dimethoate disulfoton	
New York	17625 A	10	FS	1	aphids mites	dimethoate disulfoton	
Alabama	4365 A	3	FS	2	leafminers pine tortoise scale	demeton bendiocarb acephate	3 3
Indiana	400 A	80	FS	2.5	aphids leafhoppers mites pine needle scale	methyl parathion methyl parathion dienchlor acephate	4 2 1 2
Ohio	40 A	10	FS	2.5	aphids mites leafminers	fluvalinate dienchlor	2.5 2.5
Tennessee	5000 A	10	SI	1	wooly apple aphid	disulfoton	1

<sup>a</sup>No usage reported by Alabama, Florida, Illinois, Ohio, Mississippi, and Vermont.<sup>b</sup>Greenhouse usage reported in ft<sup>2</sup>, field usage reported in acres (A).<sup>c</sup>FS = foliar spray, SI = soil injection.<sup>d</sup>Not available: information not provided by respondent.

Table 64. Comparative performance of oxydemeton-methyl and alternative chemicals for control of ornamental plant pests

Pest	Host plant	Application <sup>a</sup> method	No. applications	No. days application lasts	ODM % control	Good alternative chemicals	Poor alternative chemicals	Source
<b>Scales</b> euonymus scale	japanese euonymous	FS	3	na	51	methidathion, bendiocarb, thiodicarb, acephate, oxamyl	None	Williams (1981)
hemispherical scale	dwarf euonymous	FS	1	na	99	bendiocarb, methidathion, methomyl	dimethoate, oxamyl	Williams (1980)
Fletcher scale	Taxus	FS	1	14	97	azinphos-methyl, methidathion, dimethoate, oxamyl		Kennedy (1981)
Florida wax scale	Burford holly	FS	1	na	87	methidathion, methomyl, bendiocarb, dimethoate, oxamyl		Hudson (1980)
tea scale	Burford holly	FS	1	na	71	methidathion, oxamyl, bendiocarb, dimethoate, methomyl		Ray (1980)
<b>Whiteflies</b> citrus whitefly	gardenia	FS	1	14	80	acephate, dimethoate	resmethrin, fluvalinate, methomyl, Enstar	Stephenson (1985)
greenhouse	Chrysanthemum	FS	1	21	good	methoxychlor, malathion, acephate, disulfoton, mexacarbate	Vittum (1982)	
<b>Defoliators</b> bagworm	arborvitae	FS	1	3	93	diazinon	diazinon, carbaryl, <i>B. thuringiensis</i>	Ree (1981)
mimosa webworm	honey locust	SD	1		good			Caldwell (1985)
<b>Aphids</b> chrysanthemum aphid	chrysanthemum	FS	1	7	100	chlorpyrifos, permethrin, Pirimor, oxamyl	resmethrin	Bodri (1982)
greenbug	Kentucky bluegrass	FS	1	7	98	acephate	chlorpyrifos, isotenphos	Kennedy (1983)



Table 64. (continued)

Pest	Host plant	Application <sup>a</sup> method	No. applications	No. days application lasts	ODM % control	Good alternative chemicals	Poor alternative chemicals	Source
<b>Borers</b> bronze birch borer	white birch	FS	3	365	poor	dimethoate, acephate, fenvalerate, lindane, oxamyl, chlorpyrifos, bendiocarb	bendiocarb, chlorpyrifos, lindane	Nielsen (1982); Nielsen (1983); Akers (1982)
<b>Other pests</b> hawthorn	pyracantha	FS	1	7	100		bendiocarb	Manuel (1980)
striped mealybug	episcia	FS	4	7	good	ethion, acephate, aldicarb	Pirimor, endosulfan	Price (1980)
pine needle midge	scotch pine	MB	2	90	good	fenvalerate, cyfluthrin	acephate, Alysystin	Sapio (1985)
spruce spider mite	Fraser fir	FS	1	49	good	dicofol, dimethoate, ethion	endosulfan	Neuleton (1978)

<sup>a</sup>FS = foliar spray, SD = soil drench, MB = mist blower.

## REFERENCES

- Agnello, A. M. 1986. 1987 Fruit insect and mite control recommendations for New York State. pp. 198-236. In 1987 New York State Pesticide Recommendations. Cornell Univ., Ithaca, New York. 504 pp.
- Agnello, A. M. 1987. 1988 fruit insect and mite control recommendations for New York state. pp. 189-238. In 1988 New York State Pesticide Recommendations. Cornell Univ., Ithaca, New York. 548 pp.
- Akers, R. C. and D. G. Nielsen. 1982. Bronze birch borer control on European white birch. Insecticide and Acaricide Tests. 7:209.
- AliNiazee, M. T. 1980. Filbert insect and mite pests. Oregon State Univ., Agric. Exp. Sta. Bull.643: 1-13. Anonymous. 1982. Integrated pest management for walnuts. Univ. Calif., IPM Project, Div.Agric. Sci. Pub. 3270. 97 pp.
- Andrilenas, P.A. 1975. Farmers' Use of Pesticides in 1971-Extent of Crop Use, pp. 1-25. U.S. Dept. Agric., Econ. Res. Serv., Agric. Econ. Rept. 268.
- Anonymous, 1979. The Biologic and Economic Assessment of Dimethoate. USDA Tech. Bull.#1663. 279pp.
- Anonymous. 1986. Chapter V. Statistics of Fruits, tree nuts, and Horticultural specialties. pp.184-235. In Agricultural Statistics. U.S. Dept. Agr., Nat. Agr. Statistics Ser. Wash. DC.
- Anonymous, 1986. Pesticide Use Report, Annual 1986. Calif. Dept. Food and Agr., Sacramento California.
- Anonymous, 1988. New York State Pesticide Recommendations. Cornell, Univ., Ithaca, NY.
- Anonymous. 1989a. Crop Protection Chemicals Reference. Chemical and Pharmaceutical Press. New York, New York. 2330 pp.
- Anonymous. 1989b. Toxicity of certain pesticides. In Farm chemicals handbook. Meister Publ.Co. pp. c315-c318.
- Antonelli, A. L., C. H. Shanks, Jr., and G. L. Fisher. 1988. Small fruit pests - biology, diagnosis, and management. Wash. State Univ., Coop. Ext. Ser. Publ. EB 1388. 20 pp.
- Arriaga, H.O., H.O. Chidichimo, and L.B. Almaraz. 1983. Evaluation de resistencia a pulgon verde *Schizaphis graminum* (Rond) en trigo. (In Es.) Revista de la Facultad de Agronomia. Universidad Nacional de La Plata 56:53-60.
- Baiecki, A. 1988. per. comm., West Virginia Univ., Morgantown 10/24/88
- Baird, C.R. and H.W. Homan. 1986. Insect control recommendations for mint production in Idaho. Idaho Current Information Series 773.
- Barnett W.H. and H.G. Smith. 1986. Insect and mite control for alfalfa seed production in Nevada. University of Nevada Reno Pub. 86-16.
- Beers, E. H. 1988. 1988 Spray guide for tree fruits in Eastern Washington. Wash. State Univ., Coop Ext. Ser. Publ. EB 0419. 89 pp.
- Beers, E. H. & E. A. Elsner. 1989. Apple aphicide test, 1987. Insect. & Acar. Tests 14: 3.

- Berry, R.E. 1977. Insects on mint. PNW 182. Oregon State University.
- Bodri, M. and R. D. Oetting. 1982. Control of Chrysanthemum aphid on Chrysanthemum. Insecticide and Acaricide Tests. 7:215.
- Braun, A. 1986. Tissue culture for small fruits. Penn. Fruit News. 65(4):75-76.
- Brindley, W.A. 1975. Insecticide bioassays with field populations of alfalfa weevils, a simplified approach. J. Econ. Entomol. 68:227-30.
- Brindley, W.A., D.H. Al-Rajhi, and R. L. Rose. 1982. Portable incubator and its use in insecticide bioassays with field populations of lygus bugs, aphids, and other insects. J. Econ. Entomol. 5:758-60.
- Brindley, W.A. and A.-A. Selim. 1984. Synergism and antagonism in the analysis of insecticide resistance. Environ. Ent. 13:348-53.
- Brlansky, R.H., R.R. Pelosi, S.M. Garnsey, C.O. Youtsey, R.F. Lee, R.K. Yokomi, and R.M. Sonoda. Tristeza Quick Decline Epidemic In South Florida. Proc. Fla. St. Hort. Soc. 99:66-69. 1986.
- Brodel, C. F., and G. A. Schaefer. 1980. Use of exercised leaflets of red raspberry to screen for potential nonpreference resistance to *Amphorophora agathonica*. HortSci. 15(4): 513-514.
- Brooks, R.F. Control of Aphids on Florida Citrus. Proc. Fla. St. Hort. Soc. 81:103-105. 1968.
- Brown, G. C. and C. H. Shanks. 1976. Environ. Entomol. 5:1155-9.
- Brunner, J. F., and A. J. Howitt. 1981. Tree fruit insects. North Central Region., Coop. Ext.Publ. No. 63. 60 pp.
- Caldwell, D. L., E. J. Kunickis, and B. G. Joyner. 1985. Control of mimosa webworm with soil-applied Metasystox-R. Insecticide and Acaricide Tests. 10:296.
- Calkin, J. and G. Fisher. 1982. A guide for insect pest management on peppermint in Oregon. Oregon State University.
- Capizzi, J. cite author 1. 1988. Pacific northwest insect control handbook. Extension services of Oregon State University, Washington State University and University of Idaho, pp 176-179.
- Capizzi, J. 1988. Pacific Northwest Insect Control Handbook. 320 pp.
- Cartwright, R. 1985. Insect. and Acar. Tests. 10:111-12.
- Cartwright, R. 1988. per. comm., Oklahoma St. Univ., Stillwater 11/11/88.
- Castaldi, M. 1987. The cost of establishing and producing small fruits for Pick Your Own and commercial harvest. Department of Pomology, Cornell University, Ithaca, New York. Misc. Publication. 24 pp.
- Caulkin, J. and G. Fisher. 1989. Scouting and decision-making guide for filbert insect pests. Oregon State Univ. Extension Bull. (in prep.)
- Cohick, A. D. 1988. Metasystox - R Special Review - User Benefits. Metasystox- R Rept. # 87254. Mobay Chemical Co.



- Cohick, A. D. 1988. Metasystox - R Special Review - User Benefits. Metasystox- R Rept. # 87254. Mobay Chemical Co.
- Colby, A. S., H. W. Anderson, and W. P. Flint. 1940. Bramble fruits: raspberries, blackberries, and dewberries. Univ. Illinois Agr. Exp. Stn. Circ. No. 508. 72 pp.
- Croft, B. A. 1975. Integrated control of apple mites. Univ. Mich., Coop. Ext. Ser. Bull. E 825. 12 pp.
- Cutright, C. R. 1963. The European red mite on Ohio. Ohio Agr. Exp. Stn., Res. Bull. 953. 32pp.
- Daniel, D. M. 1928. Biology and control of the blackberry leafminer. New York State Agr. Exp. Stn. (Geneva) Tech. Bull. No. 133. 38 pp.
- Delvo, H., L. Hansen, R. Nehring, M. Gill, S.G. Daberkow, H. Taylor, and H. Vroomen. 1988. Agricultural Resources: Inputs: Situation and Outlook Report. U.S. Dept. Agric., Econ. Res. Serv., AR-11.
- Dennehy, T. J., J. J. Granett, and T. F. Leigh. 1983. Relevance of slide-dip and residual bioassay comparisons to detection of resistance in spider mites. J. Econ. Entomol. 76: 1225-1230.
- Dennehy, T. J., E. E. Grafton-cardwell, J. Granett, and K. Barbour. 1987. Practitioner-assessable bioassay for detection of dicofol resistance in spider mites (Acari: Tetranychidae). J. Econ. Entomol. 80: 998-1003.
- Dennehy, T. J., J. P. Nyrop, W. H. Reissig, and R. W. Weires. 1988. Characterization of resistance to dicofol in spider mites (Acari: Tetranychidae) from New York apple orchards. J. Econ. Entomol. 81: 1551-1561.
- Dustan, G. G., and T. R. Davidson. Rev. 1973. Diseases, insects and mites of stone fruits. Agr. Canada Publ. 915. 60 pp.
- Ehler, L.E. 1974. A review of the spider mite problem on grain sorghum and corn in West Texas. Tex. Agric. Exp. Stn. Bull. 1144, 15 pp.
- Eichers, T.R., P.A. Andrienas, and T.W. Anderson. 1978. Farmers' Use of Pesticides in 1976. U.S. Dept. Agric., Econ. Statist. Coop. Serv., Agric. Econ. Rept. No. 418. 58p.
- Fasulo, T.R. and J.L. Knapp. Insects - Section V In: Florida Citrus Integrated Pest & Crop Management Handbook, Univ. of Fla. SP-14, Gainesville, FL 1987.
- Ferguson, J.J. and S.M. Garnsey. Citrus Virus and Virus-like Diseases - Section XIV. In: Florida Citrus Integrated Pest & Crop Management Handbook, Univ. of Fla. SP-14, Gainesville, FL 1987.
- Fisher, G.C., H.W. Homan, J. Capizzi, C.R. Baird. 1988. Pacific Northwest Insect Control Handbook. Oregon State University.
- Fisher, G. T. 1987. Apple aphid control on non-bearing trees, 1985-86. Insect. and Acar Tests 12:8.
- Florida Agricultural Statistics Service, Florida Agricultural Statistics - Citrus Summary 1986-87. Orlando, FL 1987.

- Florida Agricultural Statistics Service. 1988. Florida Agricultural Statistics - Citrus Summary 1986-87. Orlando, FL. 1987.
- Forsythe, H. Y., Jr. 1966. Insect and mite control experiments on tree fruits in Ohio - 1966. OARDC Zool. and Entomol. Dept. Mimeo. 28 pp.
- Forsythe, H. Y., Jr. 1967. Insect and mite control experiments on tree fruits in Ohio 1967. OARDC Zool. and Entomol. Dept. Mimeo. 19 pp.
- Forsythe, H. Y., Jr. 1970. Insect and mite control experiments on apples and blueberries in Maine - 1970. Univ. Maine, Entomol. Dept. Mimeo. 16 pp.
- Forsythe, H. Y., Jr. and F. R. Hall. 1973. Summer control of the apple aphid in Ohio. OARDC Res. Circ. 196. 19 pp.
- Glance, 1986. Coop. Extn. Bull., UC Riverside. California.
- Glass, E. H., and P. J. Chapman. 1955. Summer control of the apple aphid. J. Econ. Entomol. 48:695-7.
- Goulart, B. L. 1986. Brambles and thornless blackberries: culture and cultivars. Penn. Fruit News. 65(4): 72-75.
- Goulart, B. L. 1989. Small fruit production and pest management guide, 1989-90. Penn. State Univ., Coop. Ext. Ser. Publ. 74 pp.
- Green, R.J. 1963. Mint Farming. USDA Agriculture Information Bulletin 212.
- Harvey, T.L. and H.L. Hackaerott. 1969. Plant resistance to a greenbug biotype injurious to sorghum. J. Econ. Entomol. 62:1271-1274.
- Hendricks, L. C. 1987. Walnut pest management guidelines. Univ. Calif., Pest Mgt. Group Publ. No. 3. 19 pp.
- Hollingsworth, C.S., R.E. Berry, G.C. Fisher. 1984. A sampling plan for two-spotted spider mites in mint. PNW 251. Oregon State University.
- Homan, H.W. and C.R. Baird. 1982. Idaho insect control recommendations for alfalfa seed production. University of Idaho Current Information Series No. 231.
- Homan, H.W. and C.R. Baird. 1987. Prevent pesticide poisoning of pollinators. Idaho Current Information Series 458. University of Idaho.
- Hoy, Casey. 1988. per. comm., Ohio St. Univ., Columbus 10/17/88.
- Hoyt, S.C. 1976. Specific acaricides and carbaryl. In W.H. Upshall [ed.], History of fruit growing and handling in the United States of America and Canada 1860-1972. Regatta City Press Ltd., Kelowna, British Columbia.
- Hudson, W. G. and M. L. Williams. 1980. Dwarf burford holly, Florida wax scale control. Insecticide and Acaricide Tests. 5:177.
- Hull, J., A. L. Jones, and A. J. Howitt. 1987. 1988 Fruit Spraying Calendar. Michigan State Univ., Coop. Ext. Bull. E-154. 120 pp.
- Ivey, L. and H. Johnson. 1987. Veg. Crops - Acreage and Value at a

- Johansen, C.A. cite author 1. 1979. Alfalfa seed insect pest management. Western Regional Extension Publication 12.
- Johansen, C.A. cite author 1. 1982. Alfalfa seed integrated pest management, the northwest regional program. Special report Washington State University Cooperative Extension, Misc. Pub. 50.
- Johansen, C.W. 1982. How to reduce bee poisoning. Western Regional Extension Publication 15. Washington State University.
- Johansen, C.W., E.C. Klostermeyer, A.H. Retan, C.R. Baird. 1974. Integrated pest management on alfalfa grown for seed. EM 3755.
- Jones, A. L., A. J. Howitt, and J. Hull. 1988. Fruit spraying calendar 1989. Mich. State Univ., Coop Ext. Ser., Bull. E-154. 177 pp.
- Kamble, D. 1988. per. comm., Univ. Nebraska. Lincoln 10/31/88.
- Keaster, A. 1988. per comm., Univ. Missouri, Columbia 11/14/88.
- Kennedy, G. G., and G. A. Schaefers. 1974. Evaluation of immunity in red raspberry to *Amphorophora agathonica* via cuttings. J. Econ. Entomol. 67(2): 311-312.
- Kennedy, G. G., G. A. Schaefers, and D. K. Ourecky. 1973. Resistance in red raspberry to *Amphorophora agathonica* Hottes and *Aphis rubicola* Oestlund. HortSci. 8(4): 311-313.
- Kennedy, M. K. and J. D. Haefner. 1981. Fletcher scale control on *Taxus*. Insecticide and Acaricide Tests. 6:167.
- Kennedy, M. K. and J. Rodencal. 1983. Greenbug aphid control in Kentucky bluegrass turf. Insecticide and Acaricide Tests. 8:65.
- Kindler, S.D., R. Staples, S.M. Spomer, and O. Adeniji. 1983. Resistance of bluegrass cultivars to biotypes C and E greenbug (Homoptera: Aphididae). J. Econ. Entomol. 76:1103-1105.
- Knapp, J.L., D.P.H. Tucker, J.W. Noling, and V.V. Vandiver, JR. Florida Citrus Spray Guide, Univ. Fla. Fir. 393-0, Gainesville, FL. 1989
- Kovach, J., L. Seyler, F. Dellamano, J. Langenstein, F. Wiles, D. Breth, and M. Holt. 1988. Small fruit IPM scouting program. pp F9-10. In Abstracts of 1987 Projects. papers presented at the 4th Annual IPM Workshop, Ithaca, NY, Jan. 20-21, 1988. 128 pp.
- Landing, J.E. 1969. American Essence: A History of the Peppermint and Spearmint Industry in the United States. Kalamazoo Public Museum. Kalamazoo, Michigan.
- Lara, F.M., A.J.B. Galli, and A.C. Busoli. 1983. Tipos de resistencia de *Sorghum bicolor* (L.) Moench a *Schizaphis graminum* (Rondani 1852) (Homoptera: Aphididae). Cientifica 9:273-280.
- Maddy, K. T. 1986. Memorandum to Calif. Dept. of Food and Agr., 7/24/86.
- Madsen, H. F., and M. M. Barnes. 1959. Pests of pears in California. Univ. Calif., Agr. Exp.Stn., Coop. Ext. Ser. Circ. 478. 40 pp.
- Maloy, O.C. and C.B. Skotland. 1969. Diseases of Mint. Extension Circular 357. Washington State University.



- Manuel, K. L., N. J. Bedwell, and M. L. Williams. 1980. *Pyracantha*, hawthorn lace bug control. *Insecticide and Acaricide Tests*. 5:183.
- Marcroft, J. E. 1986. In Volume 11: Response to Proposed Changes in the Registration of Metasystox-R Noticed by the Calif. Dept. of Food & Agr. on May 19, 1986. J. E. Marcroft, Inc., Salinas, California.
- Mayer, D.F. and C.A. Johansen. 1988. How to reduce bee poisoning from pesticides. Western Regional Extension Publication 15.
- Mayer, D.F., J.D. Lunden, and E.R. Misiczky. 1988. Integrated pest and pollinator investigations. Washington State University (unpublished reports).
- Mills, W. D., and J. E. Dewey. 1934. Diseases and insects of small fruits. Cornell Univ. Coop. Ext. Bull. No. 306. Ithaca, New York. 56 pp.
- Mobay Corp. 1989. Metasystox-R Label. Mobay Corp. Agr. Chem. Div., Kansas City, Mo. 12 pp.
- McCalley, N. F. and Der-I Wang. 1972. Field evaluation of insecticides for control green peach aphid and alfalfa looper on head lettuce. *J. Econ. Entomol.* 65:794-6.
- McCalley, N. F. 1976. *Insect. and Acar. Tests*. 1:p-40.
- Nettleton, W. A., F. P. Hain, and R. J. Monroe. 1978. Field evaluation of acaricides for control of Oligonychus ununguis in Fraser fir plantations. *J. Econ. Entomol.* 71(1):113-114.
- Nielsen, D. G. and M. J. Dunlap. 1982. Bronze birch borer control on European white birch. *Insecticide and Acaricide Tests*. 7:209.
- Nielsen, D. G. and M. J. Dunlap. 1983. Bronze birch borer control, European white birch. *Insecticide and Acaricide Tests*. 8:62.
- Olson, W. H., W. W. Barnett, and R. E. Rice. 1987. Insects. In Prune and plum pest management guidelines. Univ. Calif., Pest Mgt. Group Publ. No. 7. 33 pp.
- Ourecky, D. K. 1969. Blackberries, currants, and Gooseberries. Cornell Univ., Coop. Ext. Bull. 1216. 8 pp.
- Peters, D.C., E.A. Wood, Jr., and K.J. Starks. 1975. Insecticide resistance in selections of the greenbug. *J. Econ. Entomol.* 68:339-340.
- Pike, K.S., C.R. Baird. and R.E. Berry. 1988. Mint root borer in the Pacific Northwest. PNW 322. Washington State University.
- Pitre, H.N. 1985. Insect problems on sorghum in the USA, pp. 73-81. Internate. Crops Res. Institute for the Semi-Arid Tropics. In Proc. of the Internate. Sorghum Entomol. Workshop, 15-21 July 1984, Texas A&M Univ., College Station, TX, USA.
- Porter, K.B., G.L. Peterson, and O. Vise. 1982. A new greenbug biotype. *Crop Sci.* 22:847-850.
- Price, J. F. and B. K. Harbuagh. 1980. Mealybug control on *Episcia* *Insecticide and Acaricide Tests*. 5:173.
- Pritts, M. P., and W. F. Wilcox. 1986. 1986 Cornell recommendations for small-fruit production. N. Y. State Coll. of Agric. and Life Sci., Cornell Univ. Ithaca, New York. 32 pp.

- Radcliffe, T. 1988. per. comm., Univ. Minnesota, St. Paul 11/4/88
- Ratcliffe, R.H. and J.J. Murray. 1983. Selection for greenbug (Homoptera:Aphididae) resistance in Kentucky bluegrass cultivars. *J. Econ. Entomol.* 76:1221-1224.
- Ray, C. H. and M. L. Williams. 1980. Dwarf burford holly, tea scale control. *Insecticide and Acaricide Tests.* 5:177.
- Ree, B., K. Pinkston, R. Price, J. Young, and M. Peden. 1981. Control of bagworms on arborvitae. *Insecticide and Acaricide Tests.* 6:160.
- Riedl, H., M. M. Barnes, and C. S. Davis. 1979. Walnut pest management: historical perspective and present status. pp. 15-80 In *Pest management programs for deciduous tree fruits and nuts* (Boethel, D. J., and R. D. Eikenbary, [eds.]), Plenum Publ. Co., New York, 250 pp.
- Rinker, C.M. cite author 1. 1988. Seed production practices, alfalfa and alfalfa improvement. *Agronomy Monograph No. 29* pp 985-1021.
- Royer, T. A., J. V. Edelson, and B. Cartwright. 1988. *Insect. and Acar. Tests.* 13:99.
- Sapio, F. J. 1985. Insecticide Efficacy on the pine needle midge. *Insecticide and Acaricide Tests.* 10:316-317.
- Schaefers, G. A. 1967. Aphid control in virus free raspberry nursery stock. *Farm Research.* 33(2): 14-15.
- Schaefers, G. A. 1968. Control of the aphid *Amphorophora agathonica* in raspberry nursery stock. *J. Econ. Entomol.* 61(2): 384-387.
- Schaefers, G. A. 1980. Yield effects of tarnished plant bug feeding on June-bearing strawberry varieties in New York state. *J. Econ. Entomol.* 73: 721-725.
- Simso, B. 1989. per comm., Oregon St. Univ., Malheur County 2/1/89.
- Slingerland, M. V., and C. R. Crosby. 1914. *Manual of Fruit Insects.* The Macmillan Co., New York, New York. 503 pp.
- Smith, W. W. 1942. Bramble and bush fruit insects. *Univ. Missouri Agr. Exp. Stn. Circ. No. 220.* 4 pp.
- Smith, J.C. and L. D. Newsom. 1970. *Ann. Entomol. Soc Am.* 63:460.2.
- Sorenson, K. 1988. 1988 Spray recommendations for commercial fruit growing in North Carolina. N. C. State Univ. Raleigh, North Carolina.
- Spangler, S., and A. M. Agnello. 1989. 1988 small fruit insect review. In Pritts, M. [ed.] *Cornell Small Fruits Newsletter.* Vol. IV, No. 1. Cornell Cooperative Extension Service. 12 pp.
- Starks, K.J. and K.A. Mirkes. 1979. Yellow sugarcane aphid plant resistance in cereal crops. *J. Econ. Entomol.* 72:486- 488.
- Starks, K.J. and Z B Mayo, Jr., 1985. Biology and control of the greenbug attacking sorghum, pp. 149-158. *Internate. Crops Res. Institute for the Semi-Arid Tropics.* In *Proc. Internate. Sorghum Entomol. Workshop*, 15-21 July 1984, Texas A&M Univ., College Station, TX, USA.

- Stephenson, J. C., M. L. Williams, and G. L. Miller. 1985. Citrus whitefly control. *Insecticide and Acaricide Tests*. 7:216.
- Stoltz, R. L. 1983a. *Insect. and Acar. Tests* 8:p92.
- Stoltz, R. L. 1983b. *Insect and Acar Tests*. 8:p.92.
- Taschenberg, E. F., D. F. Minnick, and J. B. Bourke. 1975. Protecting the tractor operator in the application of pesticidal chemicals. *N. Y. Food and Life Sci. Bull. No. 54(7)*: 1-6.
- Teetes, G.L. 1976. Integrated control of arthropod pests of sorghum. *In Proceedings, US-USSR Symposium: The integrated control of the arthropod, disease and weed pests of cotton grain sorghum and deciduous fruit*, pp. 24-41. *Texas Agric. Exp. Stn. Misc. Publ.* 1276.
- Teetes, G.L., C.A. Schaefer, J.R. Gipson, R.C. McIntyre, and E.E. Latham. 1975. Greenbug resistance to organophosphorous insecticides on the Texas High Plains. *J. Econ. Entomol.* 68:214-216.
- Tingey, W. M. and T. H. Kim. 1976. *Insect. and Acar. Tests*. 1:p-65.
- Travis, J. W., and D. I. Breth. 1987. Virus diseases of raspberries. *Penn. Fruit News*. 66(7): 14-16.
- USDA. 1987. *Agricultural Statistics*. U.S. Govern. Printing Office, Washington: 1987.
- U.S. Dept. Agr., SRS. *Agricultural Statistics 1986*, Washington, D.C., 1986.
- Van den Bosch, R., B. D. Frazer, C. S. David, P. S. Messenger, and R. Horn. 1970. An effective new walnut aphid parasite from Iran. *Calif. Agric.* 24(11):8-10.
- Van Driesche, R. G., and K. Hauschild. 1987. Chapter 2. Potential for increased use of biological control agents in small fruit crops in Massachusetts. pp 22-34. *In Van Driesche, R. G., and E. Carey, [eds.] Opportunities for increased use of biological control in Massachusetts.* Univ. Massachusetts, Agr. Exp. Stn., Res. Bull. No. 718. 141 pp.
- Vittum, P. J. and R. A. Mimms. 1982. Greenhouse whitefly control on potted chrysanthemum. *Insecticide and Acaricide Tests*. 7:216.
- Wadley, F.M. 1931. Ecology of Toxoptera Graminum, especially as to factors affecting their importance in the northern United States. *Ann. Entomol. Soc. Am.* 24:325-395.
- Ward, C.R. and F.M. Tan. 1977. Organophosphate resistance in the Banks grass mite. *J. Econ. Entomol.* 70:250-252.
- Wilde, G. and C. Ohiagu. 1976. Relation of corn leaf aphid to sorghum yield. *J. Econ. Entomol.* 69:195-196.
- Williams, M. L. 1980. Hemispherical scale control on dwarf evergreen euonymus. *Insecticide and Acaricide Tests*. 5:174.
- Williams, M. L. 1981. Euonymus scale control on Japanese euonymus. *Insecticide and Acaricide Tests*. 6:162-163.
- Williams, R. N., and D. S. Fickle. 1988. Field and bioassay evaluation of insecticides on raspberries, 1987. *Insect. and Acar. Tests*. 13: 68.



- Willson, H.F., and R. W. Straub. 1988. National Pesticide Impact Assessment Program Survey Form. Mimeo. 2 pp.
- Wiseman, B.R. and W.P. Morrison. 1981. Components for management of field corn and grain sorghum insects and mites in the United States. U.S. Dept. of Agric., Agric. Res. Serv., Agric. Rev. Manuals. ARM-S-18.
- Wood, E.A., Jr. 1961. Biological studies of a new greenbug biotype. J. Econ. Entomol. 54:1171-1173.
- Wood, E.A., Jr. 1971. Designation and reaction of the greenbug cultured on resistant and susceptible species of sorghum. J. Econ. Entomol. 64:183-185.
- Wood, E.A., Jr., H.O. Chada, and P.N. Saxena. 1969. Reaction of small grains and grain sorghum to three greenbug biotypes. Progress Rept. No. 618. Stillwater, OK: Oklahoma State University. 5 pp.
- Young, W.R. and G.L. Teetes. 1977. Sorghum entomology. Ann. Rev. Entomol. 22:193-218.





\* NATIONAL AGRICULTURAL LIBRARY



1022253910



NATIONAL AGRICULTURAL LIBRARY



1022253910